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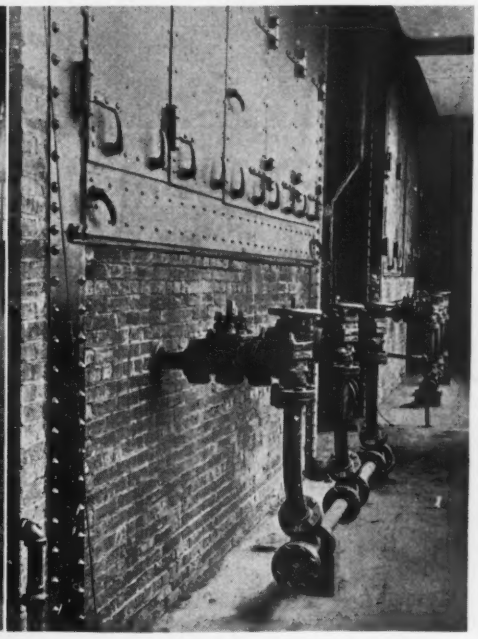
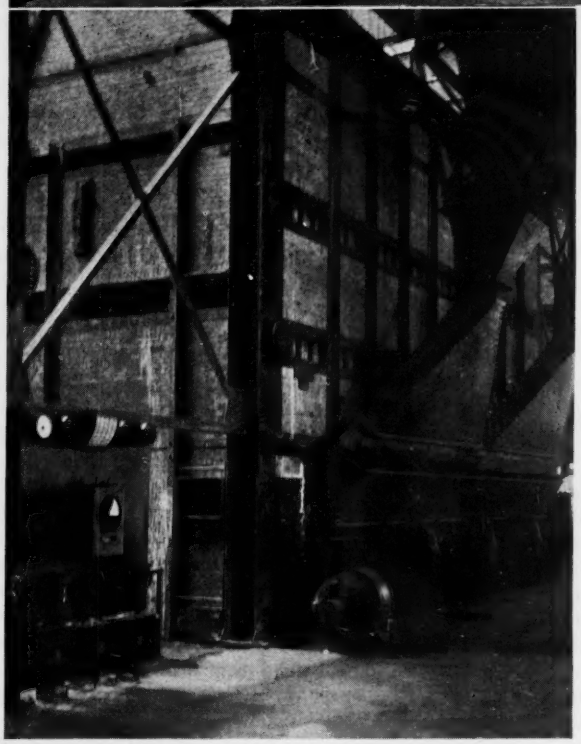


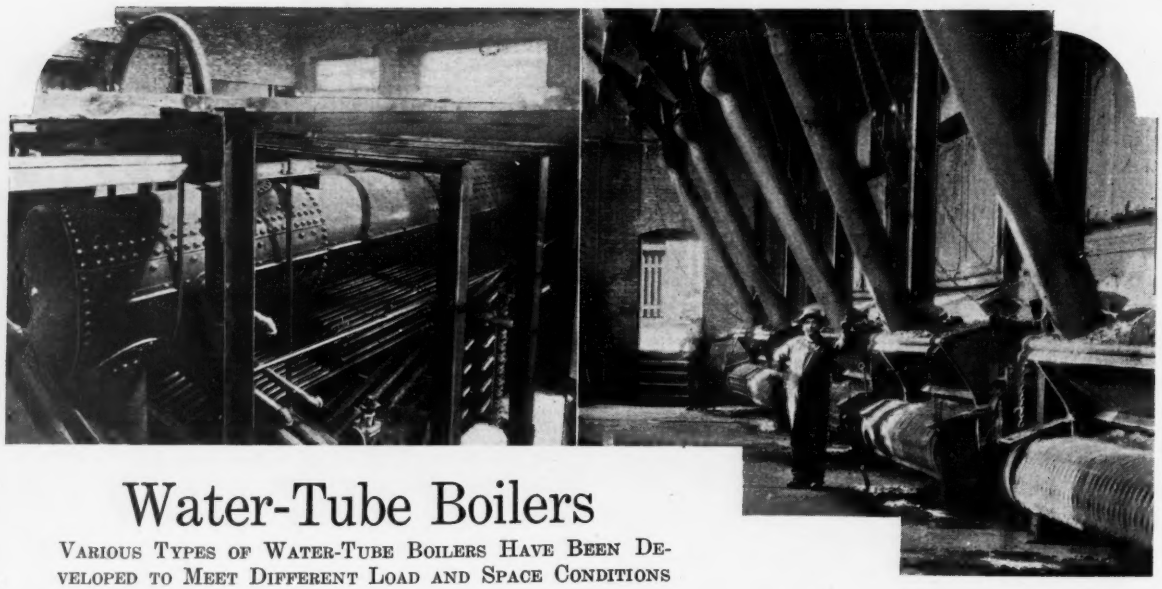


Progress

FROM the steam, spouting from the kettle's nose, which, traditionally, was Jamie Watt's inspiration, to the high-velocity jets rushing from modern huge high-pressure boilers into the racing blades of turbines is an advance won, not by any waving of a magic wand, but by wearisome often disappointing experiment and hard clear thinking.

Often improvements in methods, which science and logic approved, have had to wait for better materials and workmanship to become available. Proposals to do things differently from the customary way are generally met with adverse opinion, sometimes with ridicule. But, if they conform with scientific truth, success and general adoption will eventually come.

To know what has been tried and found wanting; to be familiar with present successful practice; to understand, clearly, the science underlying such practice and how far it falls short of perfection; to study earnestly how imperfections may be overcome, weighing carefully advantages and disadvantages of innovations. These are the foundation on which dependable, permanent progress is builded.



Water-Tube Boilers

VARIOUS TYPES OF WATER-TUBE BOILERS HAVE BEEN DEVELOPED TO MEET DIFFERENT LOAD AND SPACE CONDITIONS

ADVANCEMENT in any industry does not progress evenly in all its branches. The master minds seem naturally to concentrate all efforts on perfecting one branch at a time. This trend is notably true in the power plant field where, during the past decade, greatest progress has been made in the design, construction and operation of boilers and furnaces. Designs have been greatly improved, materials employed are more dependable and boiler construction has become standardized in many respects.

Although all types of boilers have benefited by the intensive study given the subject in recent years, greatest changes have been made in the arrangement of water-tube boilers as this type offered, and still offers, opportunities for originality in design to meet specific conditions surrounding the plant to be built. Consideration will therefore be given, in this issue, first to the water-tube boiler, the various types and details of different makes.

TYPES OF WATER-TUBE BOILERS

Water-tube boilers are made up of tubes connected to headers and drums with the water and steam on the inside of the tubes, and the hot gases flowing in contact with the surfaces on the outside. By proper arrangement of tubes and drums, boilers may be built of almost any desired capacity and for extremely high pressures, as the drums are not subject to the direct heat of the furnace and can be made smaller in diameter than with boilers of other types.

Boilers of the horizontally inclined type, as exemplified in Fig. 1, page 7, and Fig. 13, page 11, consist of a nest of straight tubes set slightly inclined to the horizontal in staggered vertical rows, the ends of the tubes being expanded into headers or water legs which communicate with the drum or drums above. The drum may run longitudinally or crosswise of the boiler, the latter being the more recent development and used most extensively for large units. Water circulates from the drum down the rear header to the lower ends of the tubes, then up through the inclined tubes to the front header, which conducts the steam and water to the drum for delivery to the steam piping or for recirculation.

Opposite the tube ends in the headers, handholes are provided for convenience in cleaning the tubes and making repairs. The mud drum is located beneath the rear headers or in case water legs are used, a sediment pocket is formed at the lowest point to which the blowoff pipe is connected.

In most cases, the furnace is located beneath the front or upper end of the tubes, which arrangement exposes a portion of the tubes to direct radiation from the fuel bed. The hot gases are directed either across the tubes making three or four vertical passes or along and parallel to the tubes making two or three horizontal passes. Vertical or horizontal baffles are used to direct the flow of the gases in the desired paths.

BOILERS USING VERTICAL AND HORIZONTALLY INCLINED TUBES

What may be termed the combined horizontally inclined and vertical type of water-tube boiler, such as illustrated in Fig. 5 on page 8, has, essentially, three nests of bent tubes which connect three drums into which their ends are expanded. The drums are so located that the connecting tubes form roughly a triangle, one section of which is directly over the furnace and inclined about 30 deg. to the horizontal; the second section lies more nearly horizontal but the connected drums have a sufficient difference in elevation to keep the front drum always filled with water, the third section connects drums that are one directly above the other so that the tubes are vertical with the exception of the ends which are bent so as to enter the drum radially. In most cases, a fourth drum is provided from which the steam is drawn to the piping system. This is ordinarily connected to the steam and water drum through tubes arranged to cause some superheating.

Baffling is so arranged that the circulation of the water in the boiler is up through the inclined sections and down through the vertical section. Access to the inside of the drums and tubes is gained through man-

holes in the drum heads. Sediment precipitated from the boiler water collects in the lower or mud drum from which it is discharged through the blowoff.

By extending the length of the drums, adding more tubes and providing larger furnace space, this type of boiler may be built in units of any capacity up to the maximum desirable for any installation.

Water-Tube Boilers with Vertically Inclined Tubes

Vertically inclined boilers are made up of sections of water tubes which connect the mud drum or two or more steam and water drums, as will be noted in Fig. 4, page 8 and Fig. 6, page 9. The front section is inclined over the furnace at an angle of about 30 deg. from the vertical while the other sections approach more nearly the vertical position.

Baffling is so arranged that the gases travel parallel to the tubes in types employing bent tubes while in one make employing straight tubes the gases pass across the tubes. Radiant heat is absorbed by the front section of tubes which is inclined over the furnace.

In some cases, the back section is used as an economizer as the gases have become cooled to about the boiling temperature of the water in the boiler while passing through the first sections of tubes. The tubes may be bent, in which case the drums lie horizontal and parallel to the front of the boiler, or, where straight tubes are used, the sections are made up of parallel units, the tubes entering the heads of the drums which have their axes parallel to the length of the tubes. These boilers may be built in units as large as may be desired by merely extending their width.

Sludge precipitated from the boiler water is drawn from the mud drum or drums, as the case may be, and manholes in the drum heads give access to the interior for cleaning.

Boilers with Vertical Tubes

Water-tubes of the vertical type may have tubes which are straight or bent, examples of these being shown in Fig. 18, page 13, and Fig. 9, page 10. Where straight tubes are employed their ends are expanded into the heads of top and bottom drums which have their axes vertical. The diameter of these drums is the limiting factor for both the capacity of the unit and the pressure which may be carried. Straight tubes have been used with drums that lie horizontal but in this case the tubes must enter the shell at an angle which creates a problem in making a tight joint at the tube ends.

Where cross drums are used, the general practice is to employ bent tubes which enter the drum radially; the tube holes are then circular and readily rolled. With this type, the size is not limited by construction features.

Vertical boilers may be arranged for either two or three passes of the gases, baffles being used to direct their path. The furnace is invariably of the extension type with the mud drum shielded from the heat of the furnace by the bridgewall. Feed water and blowoff connections are made to the mud drum and steam is taken from the top of the steam and water drum usually through some form of dry pipe. Due to the vertical tubes and the difference in temperature between the front and back tubes, the circulation of water in the boiler is rapid which is a factor in making this type of boiler a rapid steamer.

Superheat Increases Efficiency of Steam Generation and Use

IN THE ETERNAL quest for greater and yet greater economies in the power plant, the opportunities offered by superheated steam have not been lost sight of. The advantages of superheat are two-fold: It increases the efficiency of the steam generating unit, the boiler, and also of the steam using unit, the prime mover.

Superheaters are supplied in two forms, one, a separately fired unit and the other an integral unit. In the first case, the superheating surfaces are provided with a furnace entirely independent of any other in the boiler room. The advantage of this arrangement is that the degree of superheat may be varied at will to suit the judgment of the operating engineer or by careful manipulation of the fires it may be made to supply steam at a constant temperature, but it does not affect the economy or efficiency of the boiler units.

Integral superheaters may receive heat by convection from the furnace gases or by radiation from the fuel bed. Convection type superheaters may be installed anywhere in the path of the furnace gases but on water-tube boilers are usually located between the first and second passes. The location, of course, determines the average temperature to which they are subjected, consequently the amount of surface required to furnish any desired temperature. The amount of surface necessary also depends on the steam characteristics of the boiler in which the unit is fitted. A boiler that habitually delivers a relatively low quality of steam will need more superheating surface than one which supplies drier steam. The difference is more than proportional to the ratio of the quality in the two cases, as in the first instance more of the heat absorbed is supplied as latent heat to the steam.

In water-tube boilers, the superheater elements may be installed in the combustion chamber adjacent to the rear wall of the furnace, or a superheater tube may be located inside the boiler flues. The illustrations shown on page 4 will serve to indicate some of the more common ways in which superheaters are installed.

In any given boiler installation the factors involved in a determination of the amount of superheater surface required are the velocity of steam through the superheater elements; the velocity of the furnace gases over the unit; the quantity and quality of the steam to be superheated; the entrance and exit temperature of the furnace gases through the superheater; the cleanliness of the tubes; and the conductivity of the metal.

Reverting to fundamentals, the heat given up by the gases is equal to that absorbed by the steam and each is equal to the amount of heat that can be transmitted through the walls of the superheater tubes.

$$wc\ (t_1 - t_2) = Wc'\ (T_1 - T_2) = AUT$$

This is for dry saturated steam. When the steam supplied to the superheater is not saturated,

$$wc\ (t_1 - t_2) = Wc'\ (T_1 - T_2)\ (1.00 - x)\ r = AUT$$

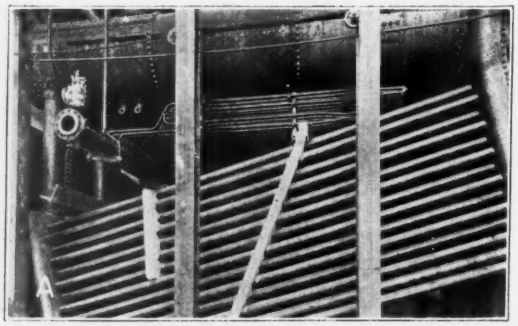
Where w = weight of gases of combustion passing through the superheater, lb. per boiler hp.-hr.

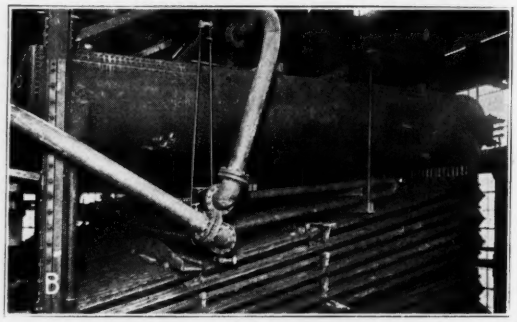
c = mean specific heat of the furnace gases

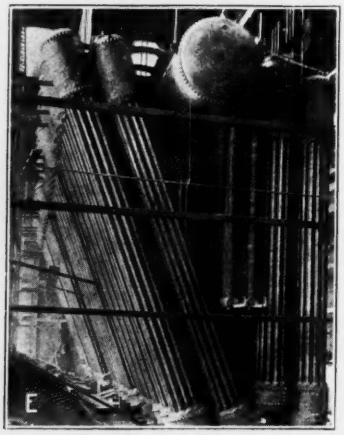
t_1 = exit temperature of furnace gases

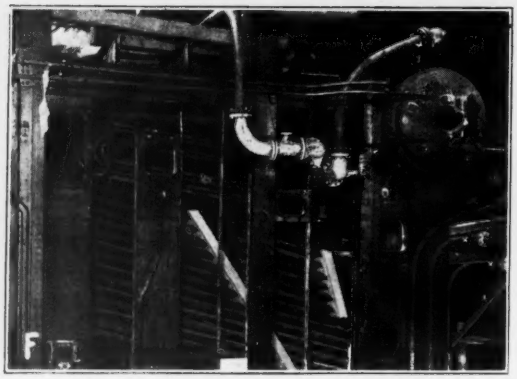
t_2 = entrance temperature of furnace gases

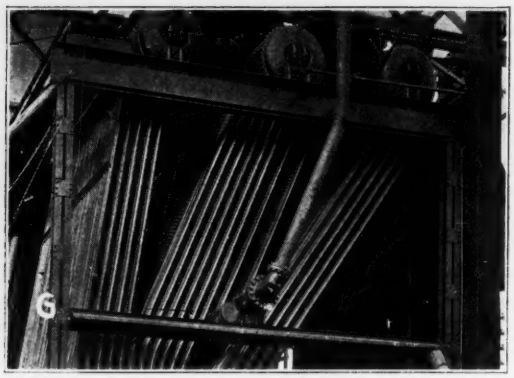
Types of Superheater Installations Are Many and Varied











A. Superheater installation on horizontal water tube boiler, between the first and second passes.

B. Tubes are provided with return bends which allow for unrestricted expansion.

C. Vertical water tube boiler showing superheater elements partially bricked in.

D. Vertical bent tube boiler with large superheating surface.

E. Vertical superheater elements in a vertical straight tube installation. Drains are provided in the headers at the bottom.

F. Superheater installed after first boiler pass. Square headers are used.

G. Convection superheater in second pass of vertical bent tube boiler.

W = weight of steam through superheater, lb. per boiler hp.-hr.

c′ = mean specific heat of the superheated steam

T_1 = temperature of superheated steam

T_2 = temperature of saturated steam

x = quality of the steam delivered by the boiler

r = latent heat of evaporation at boiler pressure

A = extent of superheating surface, sq. ft. per boiler hp.

U = coefficient of heat transmission through superheater tubes

T = mean temperature difference between the steam and the furnace gases.

For ordinary work, the mean temperature difference, T, may be the arithmetical mean as found from the relation $T = \frac{1}{2}(t_1 + t_2) - \frac{1}{2}(T_1 + T_2)$. Where greater accuracy is required, the logarithmic mean should be used. Values of U vary from 1 to 12 depending on all the factors involved in the equation for heat transfer. For units located at the end of the boiler heating surface, U = 1 to 3; for units located between the first and second passes, U = 3 to 5; for superheaters in the furnace, U = 8 to 12. In separately fired superheaters, U = 8 to 12.

An empirical expression for the area required, which can be more readily applied and which seems to conform with practice, is

$$A = 10 (T_1 - T_2) \div (2 t_1 - T_1 - T_2)$$

The value of t_1 in this equation may be found from the relation

$$1 \div (t_1 - T_2)^{0.16} = 0.172 H + 0.294.$$

Where H is the per cent of total boiler heating surface between the surface and the superheater.

For mild steel superheaters giving superheats from 100 to 150 deg. F. at a pressure of 125 lb., the area allowed in the furnace is from 0.020 to 0.025 sq. ft. per square foot of boiler heating surface; between the first and second pass 0.2 to 0.25 sq. ft.; and at the end of the boiler heating surface, 0.3 to 0.4 sq. ft.

Radiant heat superheaters are ordinarily installed as an integral part of the furnace wall. In some instances, the individual elements are placed in recesses in the wall and are separated from each other by refractory material, in others they are mounted immediately adjacent to each other and thus present practically a solid metallic steam-cooled surface to the furnace.

With this type superheater, as a heavier load is imposed on the boiler and as the rate of combustion increases, the furnace temperature rises faster than the rate of steam flow, consequently, as the per cent of rating increases, the degree of superheat increases. With the convection superheater, the reverse effect is noticed; as the rate of combustion increases, a greater proportion of the heat energy is absorbed in the first pass of the boiler and the rate of steam flow through the superheater increases faster than the temperature of the furnace gases passing over it. As a result the degree of superheat is lowered.

By combining these two types in series, these opposite effects tend to balance each other and the result, if the surfaces in each case are properly adjusted, is a practically constant steam temperature with any rate of steaming.

Water Baffling in Boiler Drums Is Needed to Prevent Priming

TWO VARIETIES of baffling are ordinarily employed in the construction of boiler drums; one serves to effect a preliminary separation of water and steam, the other prevents premature mixing of the feed water with the boiler water until the former has been heated to approximately steam temperature. Steam is formed in the boiler in the greatest quantity where the furnace temperature is the highest. The resulting mixture of steam and water passes upward through the tubes, enters the header and from there passes into the drum. Release of the steam at the surface of the water is accompanied by an active ebullition, the violence of which depends to a large extent upon the general design of the boiler and upon the amount of scale, oil or other foreign matter in the water. This geyser-like action carries considerable water along with the steam which,

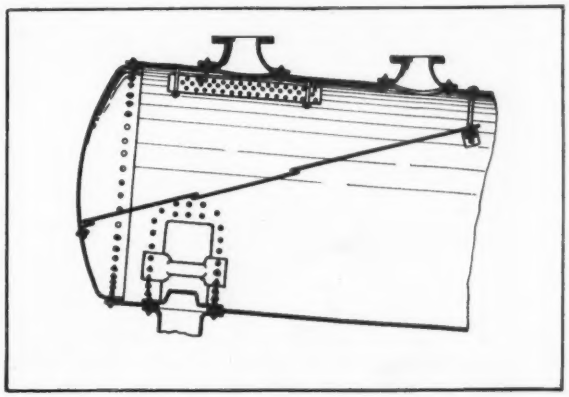


FIG. 1. INCLINED BAFFLE PREVENTS WATER SPLASHING OVER DRY PIPE

from the point of view of both safety and economy, must be separated out.

Where steam enters the drum in such a way that much of it is disengaged over a comparatively small portion of the free water surface, ebullition is violent and, unless some provision is made to take care of this condition, priming results. To deflect this rising current of steam and water so that it will reach the surface over a larger area, a baffle plate is built in the drum at an angle, over the header connection as shown in Fig. 1. Especially is this baffle necessary when the steam outlet nozzle is located directly over the front header connection as is frequently the case with this type of boiler.

In the cross-drum horizontal tube type of water-tube boiler, steam and water enter the drum through a series of tubes arranged along the entire length of the drum, consequently the distribution is more uniform, and separation of the steam is more easily accomplished. These steam-circulating tubes enter the drum at or about the normal water level; at high water, they are totally submerged and at low water, completely exposed. Through these tubes the mixture of steam and water spouts with considerable velocity and as they are quite intimately mixed this would keep the steam space filled with spray, if a deflecting baffle were not used. In practice a baffle such as shown in Fig. 2 is

employed. It is simply a piece of sheet steel riveted along one edge to the drum just above the steam tubes. The other side dips considerably below the lowest allowable water level, thus forming a water seal for the steam. Any steam discharged from the steam tubes must pass through the water under the lower edge of the baffle before it can get to the steam nozzle.

In vertical water tubes of either the straight or bent tube type, where all the tubes enter one common drum, a baffle plate forming a water seal at the lower edge is arranged over the tubes subjected to the highest furnace temperature and delivering the most steam.

In vertical water-tube boilers having more than one upper or steam drum, baffles are ordinarily unnecessary. A typical boiler of this kind has three upper drums; the front and middle drums are connected with both water

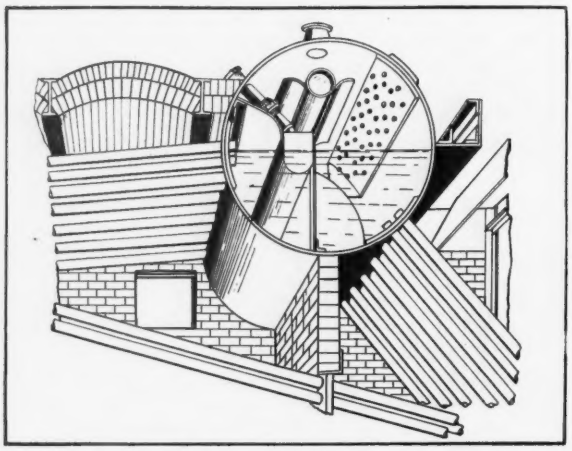


FIG. 2. ARRANGEMENT OF STEAM BAFFLE, FEED WATER TROUGH AND DRY PIPE IN A CROSS DRUM HORIZONTAL WATER-TUBE BOILER

and steam-circulating tubes and the middle and rear with only steam tubes. Steam is delivered in the greatest quantity in the front drum; thence it passes first to the middle drum which acts as a sort of receiver-separator where much of the entrained moisture is removed; and then into the rear drum where the water surface is practically inactive and where further separation takes place. Steam is taken from this drum practically dry.

Horizontal return-tubular boilers are not provided with steam baffles because the steam is disengaged more or less uniformly over the entire water surface. Unless some extraordinary condition causes excess priming or foaming, the moisture in the steam space is small.

Dry Pipes and Nozzle Baffles

All power boilers whether of the fire or water-tube type, whether they have horizontal or vertical tubes, or whether they have one or more steam drums are provided with dry pipes or their equivalent. They serve to effect a final separation of the steam and to ensure the driest possible steam being delivered to the prime mover. The ordinary dry pipe consists of a long section of pipe fitted with a tee at the center and usually fixed to the steam nozzle by means of a long nipple. This pipe is closed at the ends and drilled, along the top half, with small holes, having a combined free area several times larger than that of the steam nozzle. In some cases, the pipe is fitted with horizontal wings or baffles extending out from the pipe proper to prevent water splashing over the steam intake holes. There are many variations in the detail design of these pipes; the fabricated structure shown in Fig. 3 is a popular form.

Another form of separator used for this purpose is that shown in Fig. 4 which consists of a series of baffles arranged in series and which presents a tortuous path to the flow of steam.

Feed Water Baffles

Where boiler feed water contains scale-forming elements or other foreign material or where it enters the

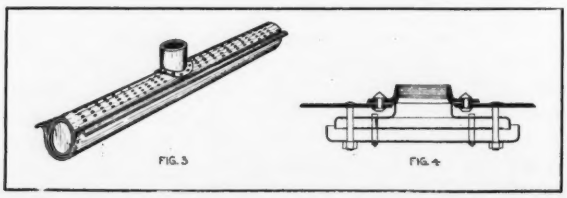


FIG. 3. FABRICATED DRY PIPE FITTED WITH SPLASH WINGS
FIG. 4. STEAM OUTLET NOZZLE BAFFLE PLATES PREVENT THE EGRESS OF WATER

boiler at a temperature lower than that of the steam, some sort of baffling arrangement should be used to provide for gradual heating of the feed and to prevent its immediately mixing with the boiler water.

By confining the feed water until it has reached the boiler temperature, much of the temporary hardness is precipitated out over a confined area where it may be readily blown off. The arrangement of baffling shown in Fig. 5 accomplishes this result.

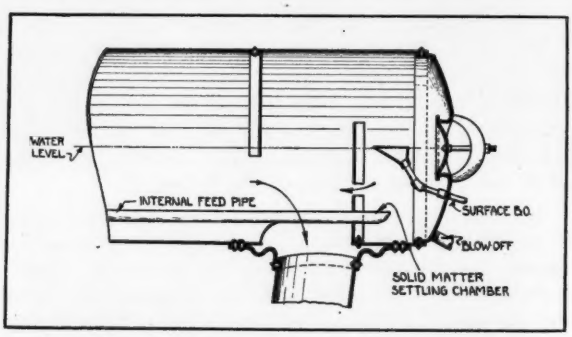


FIG. 5. FEED WATER BAFFLE PROVIDES FOR GRADUAL DIFFUSION OF FEED WATER INTO THE BOILER WATER

In some types of water-tube boilers the feed water enters an inclined mud drum immersed in the boiler water in the steam drum. The end through which the feed water enters is open, the other, lower end is closed and is connected direct to the blowoff system.

The same effect may be had by the use of a trough the edges of which are slightly above the boiler water level. The feed water enters this trough and after being heated spills over the sides and mixes with the boiler water leaving the precipitated scale in the trough whence it may be blown off. Such a device is shown in Fig. 2 with the trough part of the steam baffle.

In some instances, notably in horizontal return-tubular boilers, this effect is produced in some measure by simply running an extension of the feed pipe into the boiler for a considerable distance.

Details of Standard Water-Tube Boilers

RECENT YEARS HAVE SHOWN A TENDENCY FOR ALL BOILER MANUFACTURERS TO INCREASE THE NUMBER OF BOILER TYPES WHICH THEY BUILD

MODERN water-tube boilers are the results of developments which had their beginning with the introduction of this type in 1766. The requirements of a perfect steam boiler have gradually been evolved and a solution striven for until today we find, not the perfect boiler, but an approach to the perfect boiler which is limited only by a few practical and physical obstructions, many of which will no doubt be eliminated in the boiler of the future.

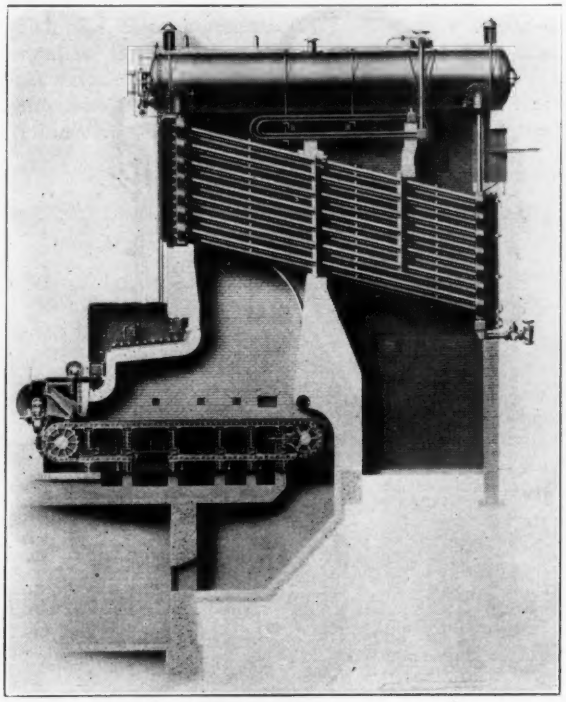


FIG. 1. BABCOCK & WILCOX LONGITUDINAL DRUM BOILER

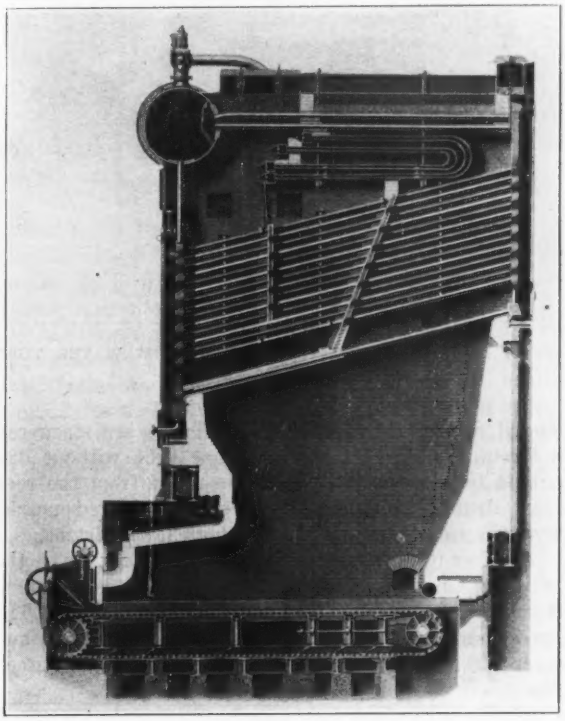


FIG. 2. CROSS DRUM BOILER AS BUILT BY THE BABCOCK & WILCOX CO.

Descriptions and illustrations which follow show the best practice of modern American design and construction. It is these boilers which are operating today at tremendous overloads in the production of a great portion of the nation's steam load.

THE BABCOCK & WILCOX CO.

Two types of inclined straight tube boilers are manufactured by The Babcock & Wilcox Co. These are the longitudinal-drum type, Fig. 1, in which one or more drums are connected to one tube nest; and the cross-drum type, Fig. 2, which has one cross drum located directly above the downtake header.

All drums have shell plates made with longitudinal seams only, except at the head connections. Drums up to and including 42 in. in diameter are made from a single plate. Drums 48 in. and larger are constructed with a single longitudinal course consisting of two plates, the butt-strap joints of which are above the water level.

Saturated steam outlets for all drums are wrought-steel high type nozzles to receive through bolts. Steam baffles and dry or collecting pipes are provided for all boilers. In longitudinal-drums, feed water enters the drum head near the uptake header connection. In cross-drums, the feed connection is also made in the head.

Headers are made in sinuous form so that the tubes are staggered, eliminating the use of header staybolts. For pressures in excess of 160 lb., the headers are made of wrought steel. In the longitudinal type boiler, the headers may be inclined or vertical and are connected to the drums by nipples expanded into the headers and into the forged-steel cross boxes which are riveted to the drums. Due to the 15-deg. inclination of the tubes, the downtake header connections are relatively long. The cross drum type of boiler does not require cross boxes. Handhole openings and inside plates are milled for the use of a thin gasket while, for outside handhole fittings, all joints are lapped for a metal to metal joint.

Down-take headers are connected by nipples at their lower ends to a 7¼ by 7¼-in. forged-steel mud drum. Blowoff connection and clean-out handholes are provided in this drum.

Four drums, connected in pairs by vertical tubes, are the essential feature of the Rust boiler, Fig. 3, as manufactured by The Babcock & Wilcox Co. The drums are transverse of the setting and each steam drum is connected to the mud drum directly below it by five rows of straight and one row of bent tubes. Water and steam-circulating tubes connect the steam drums, while water-circulating tubes connect the mud drums.

Tube sheets of all drums are pressed to form individual tube seats so that straight tubes may be ex-

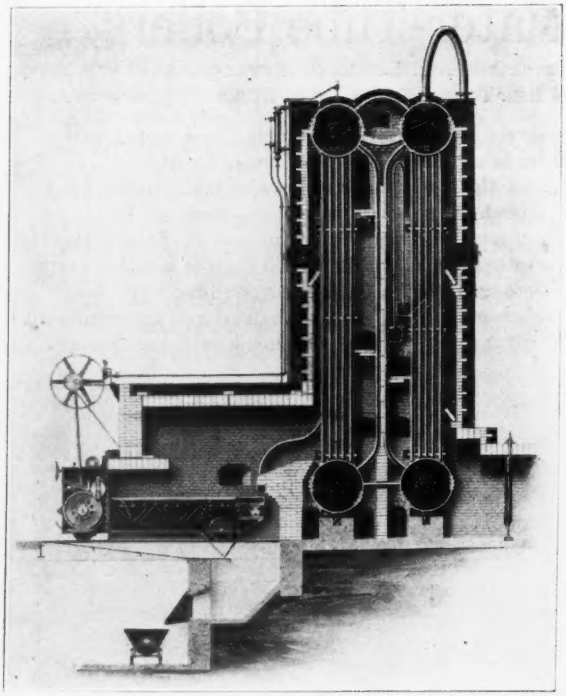


FIG. 3. RUST VERTICAL TUBE, FOUR DRUM WATER TUBE BOILER

panded directly into the drums. Tubes are staggered to facilitate the replacement of one tube without disturbing those adjacent. Steam is taken from the rear steam drum, through a dry pipe and forged nozzle. Blowoff connections are made to both lower drums.

Another product of The Babcock & Wilcox Co. is the "Stirling" boiler, shown in Fig. 4. It consists of four drums inter-connected by inclined bent tubes. The three drums on the upper level contain both steam and water although there is no water connection between the center and rear drum except through the tube banks to the lower or mud drum. Active circulation is up in the front tube bank, across to the center drum and down to the mud drum. Steam-circulating tubes connect the three upper drums.

Feed water is admitted through the rear drum head and is distributed the full length of the drum by a removable trough, being heated as it passes downward through the rear bank. Steam is taken from the rear drum because it is the least turbulent. The dry pipe serves as a steam collector, from which steam passes through a forged-steel nozzle. Drum joints are made longitudinal only, except the head seams and all seams are kept out of the direct path of the hot gas.

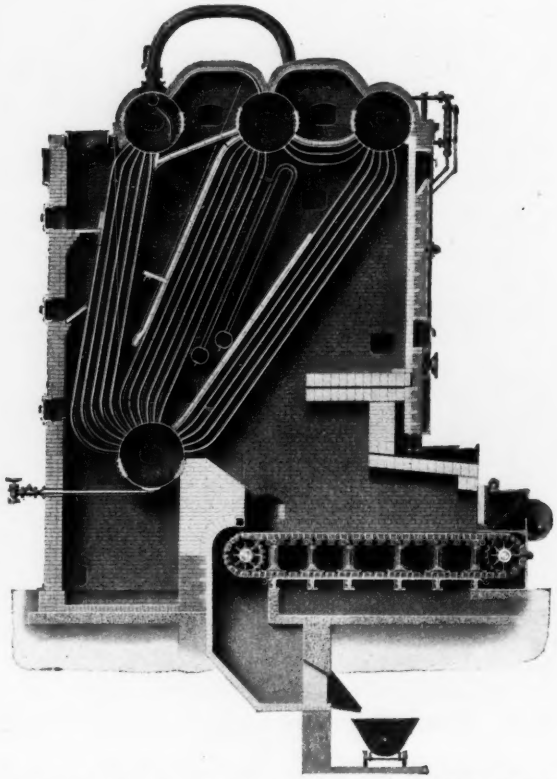


FIG. 4. STIRLING BOILERS HAVE THREE UPPER STEAM DRUMS PLACED ON THE SAME LEVEL

Tubes are arranged in straight lines with alternate spaces wide enough for tube replacement without disturbing adjacent tubes. The boiler is suspended by the upper drums, leaving the mud drum free to move with tube expansion.

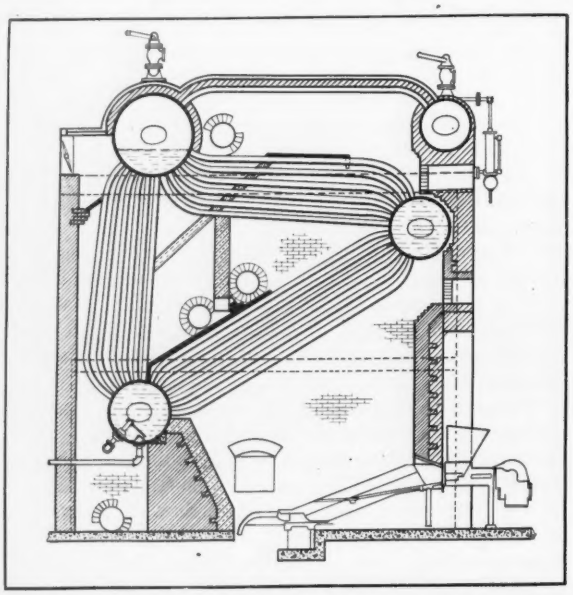


FIG. 5. SIDE ELEVATION OF THE BADENHAUSEN WATER TUBE BOILER

Phillips Badenhausen

Phillips Badenhausen places three cross drums in the path of water circulation and a fourth or superheater drum above the water line, as shown by Fig. 5. The mud drum is connected by a bank of tubes to the front drum which is below the water line. The upper or rear drum containing both steam and water is larger than either the mud or the front drum, to which it is connected by banks of bent tubes. Connection of the superheater drum to the saturated steam space is made by a single row of tubes in which the steam is slightly superheated. Feed water is introduced into the mud

drum. The large drum is supported on a steel frame work and the front drum suspended by hangers. The mud drum is free to move with the expansion of the tubes.

The Bigelow Company

Sectional construction is a feature of the Bigelow-Hornsby water-tube boiler, shown in Fig. 6. Each section is made up of four or more units, two of which are inclined over the grate while the remainder are vertical. This arrangement provides space for a cross drum just back of the two front units and at such height that the water line is approximately at its center. Each unit consists of an upper and lower drum placed so that their longitudinal axes are parallel to the tube nest which ties them together. The drum tube heads are forged so that straight tubes may be seated squarely. Unit drums and the cross drums are tied together by water and steam-circulating nipples and tubes. Baffles are placed so that the gas makes a straight pass through

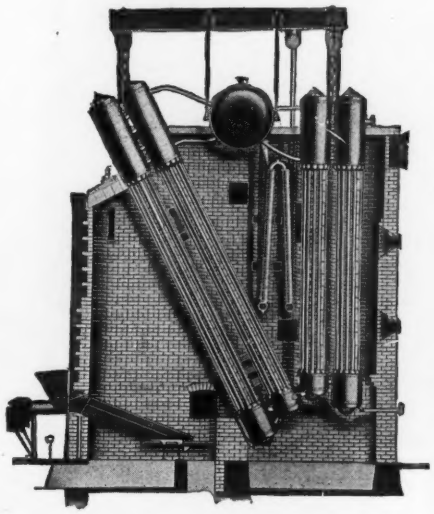


FIG. 6. SECTIONAL ELEVATION OF THE BIGELOW-HORNSBY WATER TUBE BOILER

the boiler without reverse turns. Saturated steam is taken from the cross drum while feed water enters the top rear-unit drums.

The Casey-Hedges Co.

Longitudinal drum, cross drum and vertical water-tube boilers are manufactured by The Casey-Hedges Co. The longitudinal drum type, shown in Fig. 7, consists of one or more horizontal drums to which are riveted forged steel box type headers which are connected by a nest of inclined tubes. Slots are cut in the drum at the header throat so that no additional staying is needed at that point. Opposite each tube is an oval shaped handhole which is closed by an inside forged-steel handhole plate. Each drum is fitted with a wing dry pipe, internal mud drum into which the feed water is discharged, and forged nozzle pads for steam and safety valve connections. This type of boiler is slung at the front end while the rear end rests on expansion plates and rollers which are supported on steel work.

Casey-Hedges cross drum boilers, as illustrated by Fig. 8, are constructed with a drum placed across the

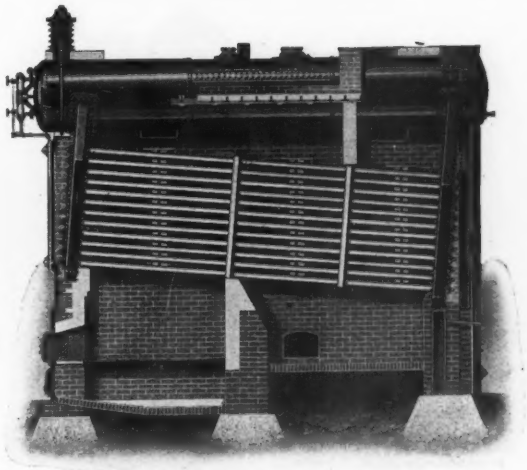


FIG. 7. LONGITUDINAL DRUM BOILER AS BUILT BY THE CASEY-HEDGES CO.

boiler at the rear end, and connected to an up-take box type header by two rows of tubes and to a down-take header by a single row of tubes. The headers are tied together by a nest of inclined tubes. Construction of the headers is in general the same as for the longitudinal type boiler. The up-take header is suspended from a steel frame and the down-take header rests on foundation plates and rollers which are carried either on masonry or, in high-set boilers, on a structural support. A new design has been perfected whereby a structural steel frame is used at the rear for supporting the boiler; the boiler drum being carried on steel saddles attached to supporting columns. The rear tube doors are also carried on the same structural steel framing.

Casey-Hedges vertical water tube boilers, Fig. 9, are made in two types; in one the drums are placed parallel with the furnace depth and in the other, known as the type X boiler, the drums are placed parallel with the furnace width. In the former there may be one or more lower drums connected to one or more upper drums by a series of tubes placed in staggered rows. These tubes are vertical with ends bent so that they meet the drum sheets at right angles.

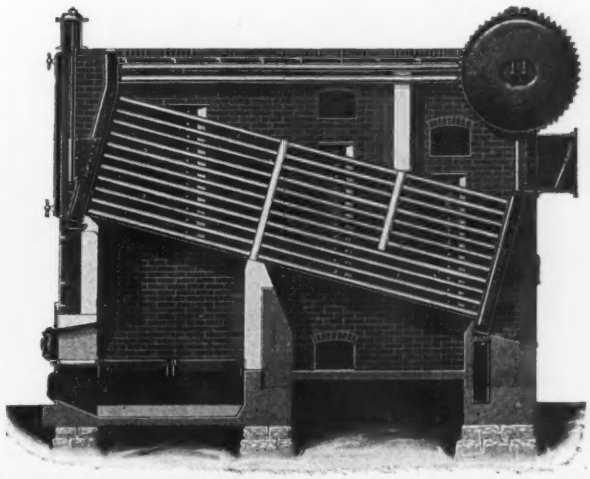


FIG. 8. CASEY-HEDGES CROSS DRUM BOILER

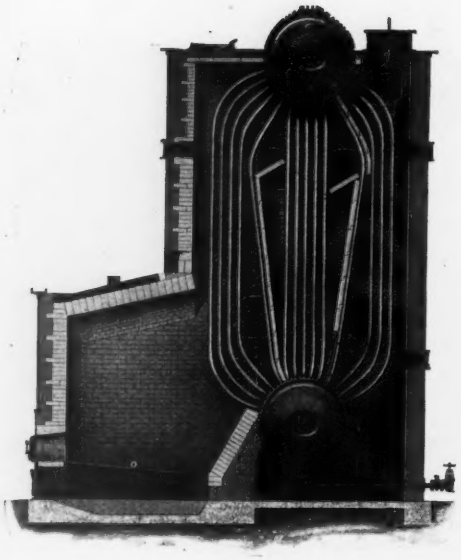


FIG. 9. VERTICAL BENT TUBE BOILER AS BUILT BY THE CASEY-HEDGES CO.

Upper drums are connected by water and steam circulating tubes and are provided with steam and safety valve nozzles. If there is more than one upper drum, their steam nozzles are tied together by a manifold connection. The lower drums are connected by water circulating tubes and are provided with feed water and blow-off connections. Baffles are vertical, providing gas passes parallel with the tubes. The upper drums are supported on steel work and the lower drums hang from the tubes.

C-H type X vertical water-tube boilers are made with an upper and lower drum which are tied together by three nests of bent tubes. Between the three nests of tubes there are sets of inclined baffle-carrying tubes. The baffles are shiplap, are carried in an inclined position and are self-sustaining. The water level is carried on the center line of the upper drum which is fitted with forged steel saddle nozzles, for steam and safety valve outlets, and a feed water connection. The lower or mud drum is provided with blowoff connections and a special baffle arrangement to maintain a uniform temperature in the drum. The gas baffles are placed vertically and arranged for three gas passes. The upper drum rests on cast saddles supported on a structural frame. The lower drum is hung from the tubes and therefore free to move with tube expansion and contraction.

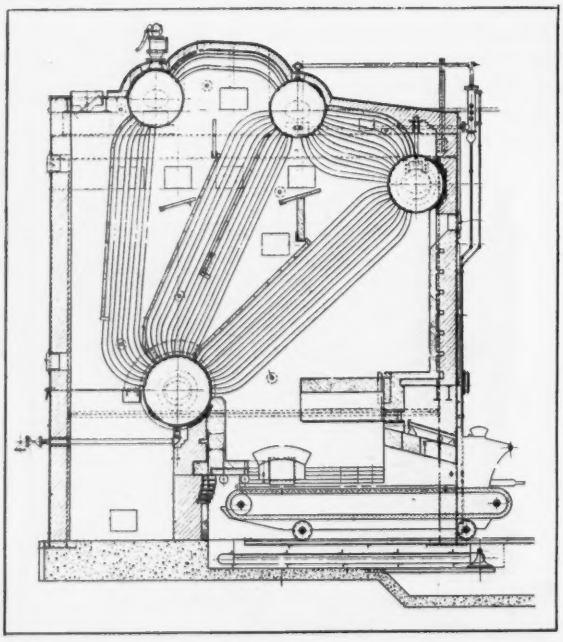


FIG. 10. FOUR DRUMS ARE USED IN THE CONNELLY BENT TUBE BOILER

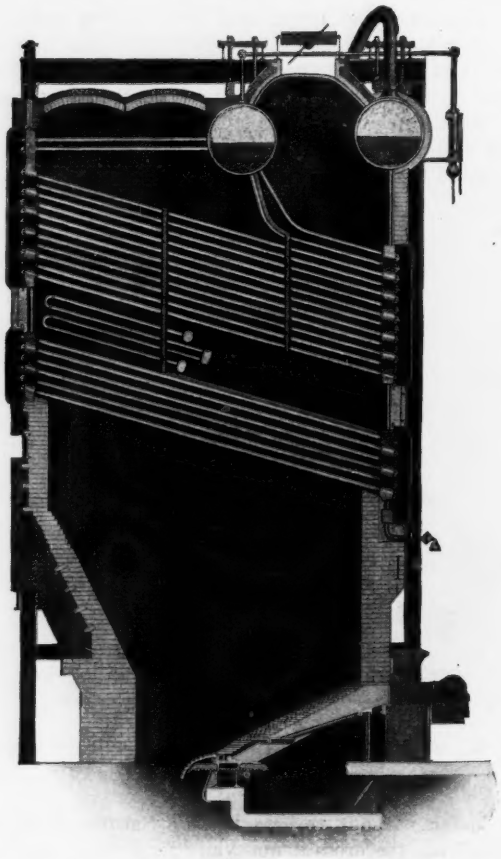


FIG. 11. CONNELLY CROSS DRUM BOILERS ARE PROVIDED WITH TWO STEAM DRUMS

THE D. CONNELLY BOILER CO.

Two types of water tube boilers are built by the D. Connelly Boiler Co.; these are the four-drum bent-tube, Fig. 10, and the straight-tube cross-drum type, as shown in Fig. 11. In the former, the three upper drums are connected by tube banks to the mud drum. Of the three upper drums, that in the rear is the highest and it is connected to the center drum by steam circulating tubes only. The middle drum is placed with its center on the water line and is connected by circulating tubes to the front drum which is below the water line.

Steel-work supports the two upper drums while the forward drum is suspended by steel rods. The mud

drum is free to move with the tube expansion. Any tube may be renewed without disturbing those next it.

Feed water enters at the top of the rear drum and is so distributed that its path will be downward through the rear tube bank. The steam nozzle is located on the highest drum. Blowoff connections are made to the low point of the mud drum.

In the Connelly cross-drum boiler, two steam drums, connected by steam circulating tubes, are placed on the same level. The front drum is placed directly above the down-take header to which it is connected by circulating tubes. The other drum is placed about central with respect to the boiler depth and it is tied in with the front and rear headers by two rows of tubes. The drums are built with but one longitudinal seam. The tubes are inclined at 15 deg.

Headers are of the sinuous steel type, the elliptical handhole plates covering two tubes. All handhole plates are of the inside bearing type with bearing surface machine finished. Steam is taken from the front drum.

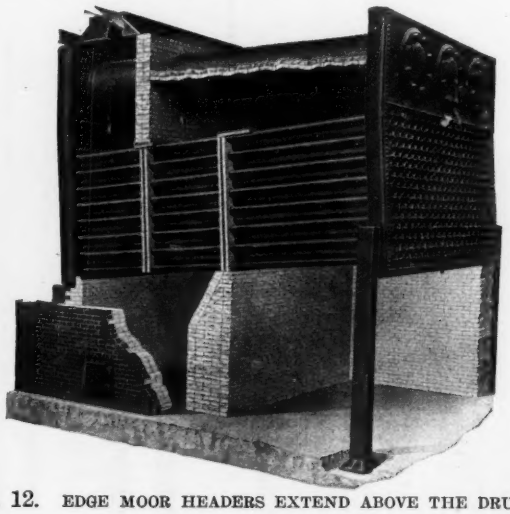


FIG. 12. EDGE MOOR HEADERS EXTEND ABOVE THE DRUMS

A square section mud box to which blowoff connections are made is attached by nipples to the lower ends of the down-take headers.

Edge Moor Iron Company

Two features are pre-eminent in the longitudinal drum boiler, Fig. 12, made by the Edge Moor Iron Co. These are the extension of the headers at full width, well above the tops of the drums, and the method of making field connections between drums and headers.

Headers are made of riveted steel plate and the flat surfaces in the tube area are stayed with either solid or hollow stay-bolts. Bulges opposite the drums are stayed by eight 2½-in. steel bolts anchored through steel U-plates riveted to the inside of the drum. The joint in the header plate is made permanently tight by annealed copper cone nuts which are drawn into the conical hole in the plate by screwing up on the outside nut before the 2½-in. stay-bolts are put in place.

Tubes are pitched slightly and staggered. Each tube end is accessible through an elliptical handhole, gaskets being used to seal the handhole cover joints. Blowoff connections are made to the under side of the lower header. Saturated steam may be taken through a dry pipe and nozzle from the tops of the drums or from near the top of the inside surface of the rear header. The latter method is often used with superheater installations.

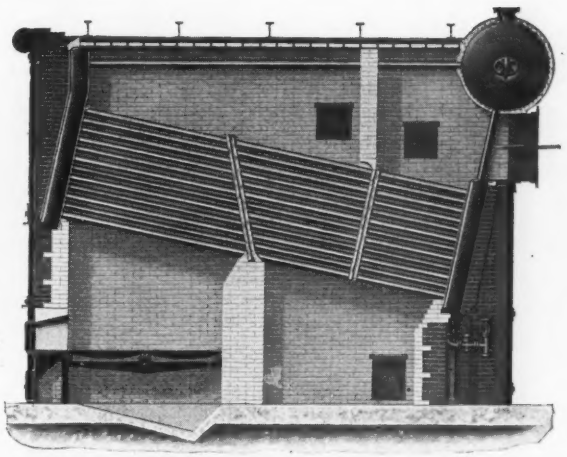


FIG. 13. EDGE MOOR CROSS DRUM BOILER SET FOR HAND FIRING

Edge Moor cross drum boilers, shown by Fig. 13, consist of a nest of inclined tubes connected to headers of the box or riveted plate type. A cross drum is placed above the rear of the down-take header to which it is connected by a single row of circulating tubes. The up-take header is connected to the drum by one or two rows of horizontal tubes. Blowoff connection is made to the bottom of the down-take header.

Erie City Iron Works

Erie City Iron Works vertical water-tube boilers, shown in Fig. 14, have an upper or steam drum con-

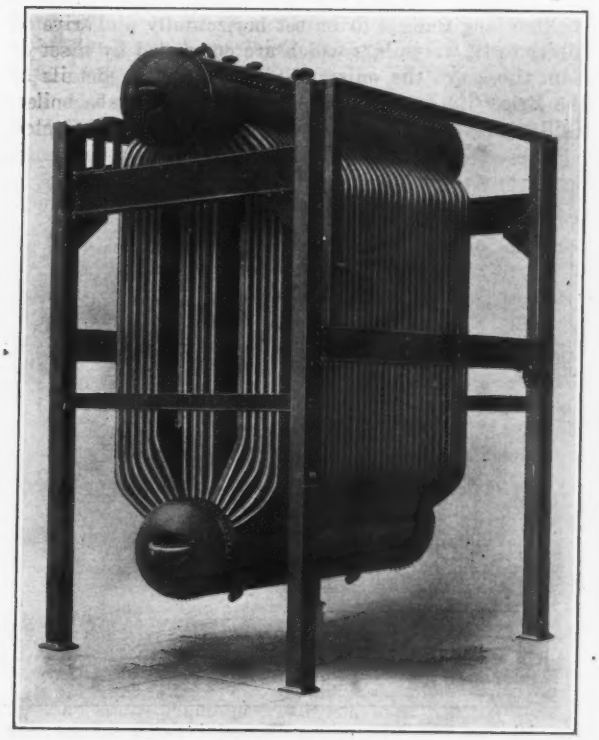


FIG. 14. ERIE CITY VERTICAL WATER TUBE BOILER

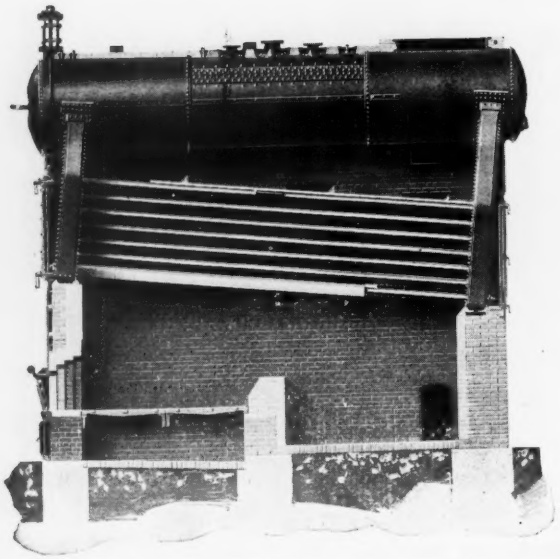


FIG. 15. ERIE CITY HORIZONTALLY BAFFLED WATER TUBE BOILER

nected by bent tubes to a water drum located directly beneath. The upper drum is supported on cast saddles which rest on a steel frame and the lower drum is suspended by the tubes. A steel baffle plate is located in the upper drum over the front bank of tubes and steam is collected by a perforated dry pipe. The feed pipe is also located in the upper drum so that the water is directed downward in the rear bank of tubes. Blowoff connections are made to the low point in the lower drum. This type of boiler requires that the furnace be set out in front. The baffling is arranged so that gas flows parallel with the tubes.

One longitudinal drum set horizontally and, riveted direct to it, water legs which are connected by a set of 4-in. tubes are the outstanding construction details of the Erie City Iron Works horizontal water-tube boiler, as illustrated in Fig. 15. Headers are built up of riveted

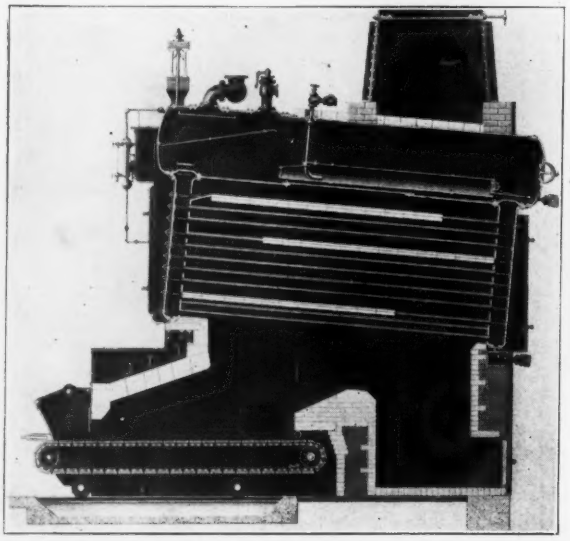


FIG. 16. IN THE HEINE LONGITUDINAL DRUM BOILER THE TUBES PARALLEL THE DRUM

plate and sloped above the tubes to meet the drum at its diameter. All flat surfaces are stayed.

Handholes are 4⅛ in. in diameter and may be provided with "Key" safety handhole caps or handhole plates and gaskets. Master handholes are provided near the bottom of each header. Tubes are pitched 5 deg.

Wrought steel flanged nozzles are provided for steam and safety valve connections. The feed pipe extends through the drum, discharging into a removable mud pan. Blowoff connections are made to the underside of the lower water leg and to the rear of the drum.

Heine Boiler Company

Heine Standard longitudinal drum boilers, shown in Fig. 16, built by the Heine Boiler Co., consist of one or more drums to which box shaped headers are riveted at each end. A tube nest parallel to the drum connects the headers. The drums are made of three sheets with double-strap butt-joint longitudinal seams and lap-joint circumferential seams and the heads are dished to a

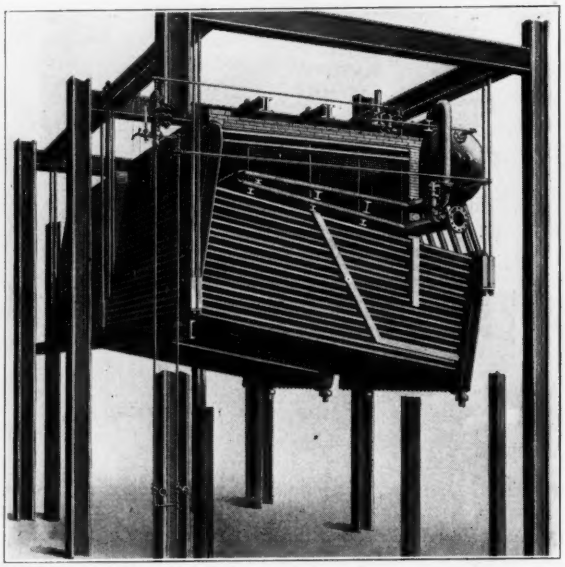


FIG. 17. HEINE CROSS DRUM BOILERS ARE SUSPENDED FROM THE HEADERS

radius equal to the drum diameter, hence require no bracing. Steam outlet and safety valves are attached to pressed steel saddles riveted to the top of the drum near the front end.

Forged steel throat stays are riveted in place at the connection between the drums and headers, and hollow staybolts are used for staying the two header sheets. All handholes are round except a few near the top and bottom. Feed water enters the drum head and is discharged into a mud pan located in the drum. A steam baffle is provided over the uptake header and a dry pipe is placed at the steam nozzle. Blowoff connections are made to the mud pan and the bottom of the downtake header.

The front end of the boiler is suspended from steel work and the rear end rests on rollers placed under the down-take header. This boiler is set with a slight inclination of the tubes and, since the tubes and drums are parallel, the water line does not parallel the axis of the drum.

Cross drum Heine boilers, shown in Fig. 17, consist of two box headers carrying a nest of inclined tubes and of a drum placed above, across and slightly to the rear of the down-take header. The drum is connected to the top of the uptake header by one or two rows of tubes and to the down-take header by a single row. A steam baffle is provided in the drum opposite the tube connection from the up-take header and a dry pipe is placed at the steam outlet. Feed water enters a mud pan located in the drum. Blowoff connections are made to this mud pan and the bottom of the down-take header. This boiler is swung from steel work at both ends.

Four drum, bent tube boilers are also built by the Heine Boiler Co. and are known as the V type and consist of three upper drums connected by banks of bent tubes to a lower or water drum as illustrated by Fig. 18. The upper drums are connected in series by both steam and water circulating tubes. Water column connections are made to the middle drum and steam and safety valve outlets are through nozzles riveted to the rear upper drum. Blowoff connections are made at two places in the bottom of the water drum. The three upper drums rest on saddles supported on structural steel work and the lower drum is suspended by the tubes. The tubes are spaced so that any tube may be removed or replaced without disturbing those adjacent to it.

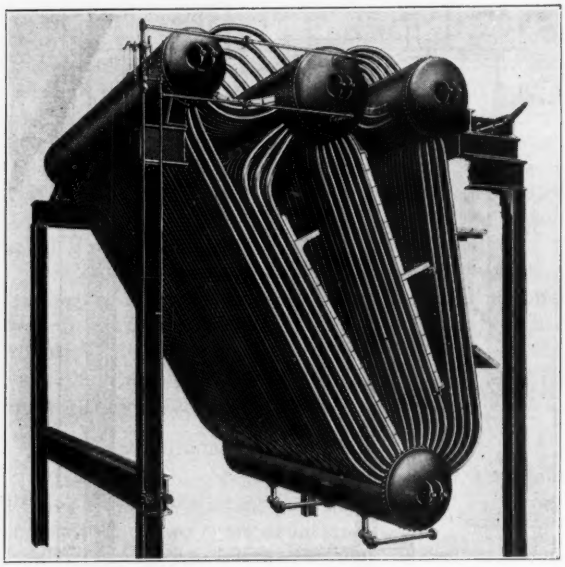


FIG. 18. CIRCULATING TUBES CONNECT THE UPPER DRUMS OF THE V TYPE HEINE BOILER

E. Keeler Company

Longitudinal and cross-drum boilers are manufactured by the E. Keeler Co. In the former, shown in Fig. 19, one or more drums may be used to which are riveted the box-form headers, giving a throat opening half the circumference of the drums. In the cross-drum type, shown in Fig. 20, the front header is connected to the drum by a horizontal row of tubes and the rear header, which is located directly under this drum, is connected to it by a row of short circulating tubes.

Tubes are pitched to influence properly the direction of circulation. Handhole plates are of the self-centering type. Feed water is introduced through the drum head and is discharged into a submerged sheet-steel mud drum which is connected with the blowoff. Connection to the blowoff is also made from the bottom of the down-take header.

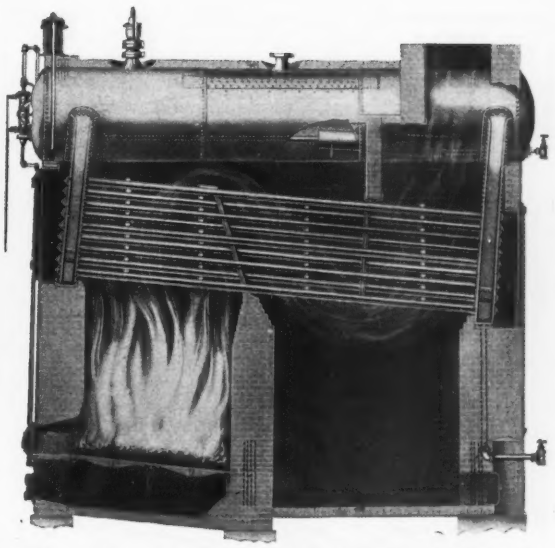


FIG. 19. SIDE ELEVATION OF THE KEELER LONGITUDINAL DRUM BOILER

The George T. Ladd Company

Boilers as manufactured by The George T. Ladd Co. are of the two and three-drum bent-tube types. The former, shown in Fig. 21, has also been developed into the four-drum and multi-drum types. In the two-drum type, one drum is placed directly above the other, the two being connected by three banks of bent tubes. The water line is carried at about the center line of the upper drum. Feed water is admitted to a feed box located within the lower drum, this feed box and the lower drum being connected to blowoffs.

In the three-drum type, shown in Fig. 22, two banks of inclined bent tubes connect the lower or mud drum with the upper forward drum, the center of which is on the water line. Circulating steam and water tubes connect this forward drum with the third drum which

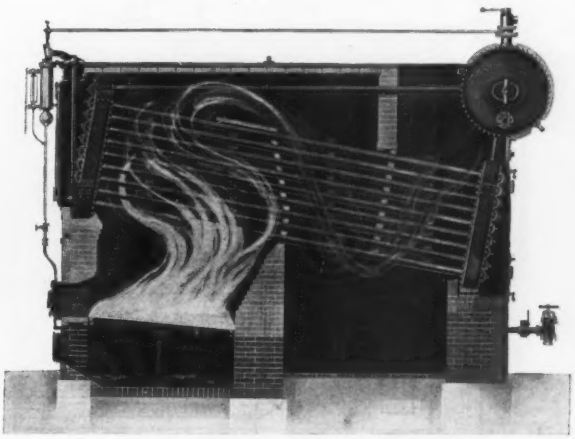


FIG. 20. HAND FIRED SETTING FOR THE KEELER CROSS DRUM BOILER

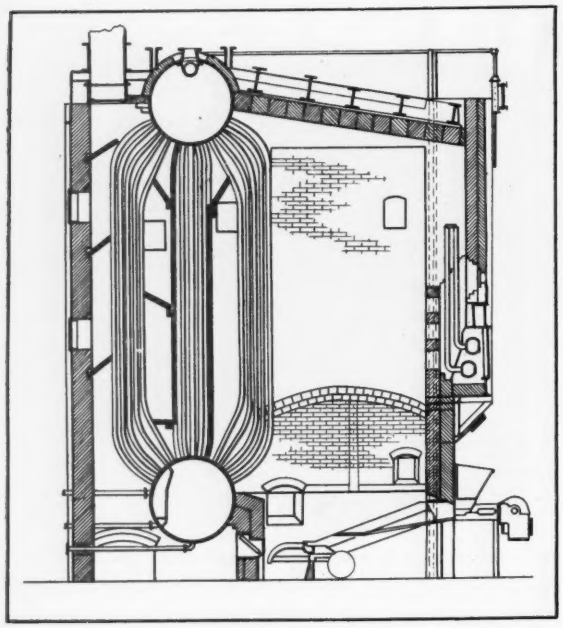


FIG. 21. SECTIONAL ELEVATION OF THE LADD TWO DRUM BOILER

is placed directly above the mud drum and at a height such that the water line will come at about its lower third. This upper rear drum and the mud drum are connected by a bank of vertical bent tubes. Feed water is admitted into a feed box in the lower drum and steam is taken from the upper rear drum.

Two complete two-drum boilers may be placed with the upper drums spaced a short distance apart and with one mud drum placed on each side of the furnace. In this way, the two units span the furnace and form the multi-drum type of boiler. Steam circulating tubes connect the two upper drums with a fifth drum to which the steam outlet nozzle is riveted.

The four-drum boiler consists of two upper drums located directly over two lower drums. Each lower drum is connected to the drum above by an outer and a center tube bank as in the two-drum type. The center tube bank connects the rear lower drum with the upper front drum. Steam circulating tubes connect the upper drums but there is no direct tie in between the lower drums. Feed water is admitted to a feed box in the rear lower-drum steam being taken from the rear upper drum. Gas flow parallels the tubes.

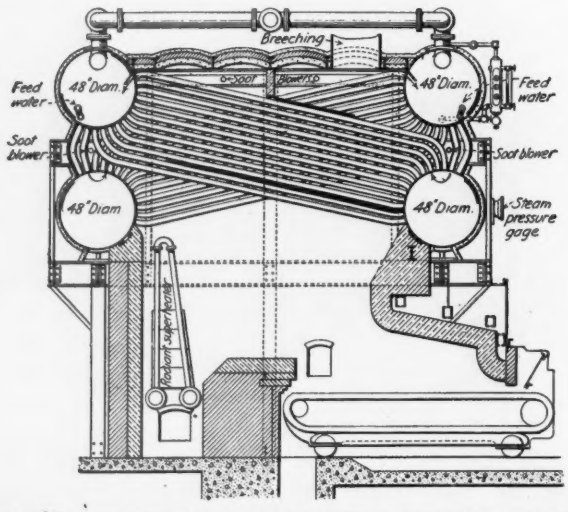


FIG. 23. BURTON FOUR-DRUM DUPLEX WATER TUBE BOILER

JOHN MOHR & SONS

Burton four-drum duplex water-tube boilers, shown in Fig. 23, are manufactured by John Mohr & Sons. They consist of four drums of the same size placed in pairs at the front and back ends of the furnace. One drum of each pair is placed directly above the other and the two are connected by two rows of short vertical tubes. The upper drum on one side is connected by vertical rows of bent tubes to the lower drum on the opposite side. The rows of tubes from the upper drums alternate across the furnace width.

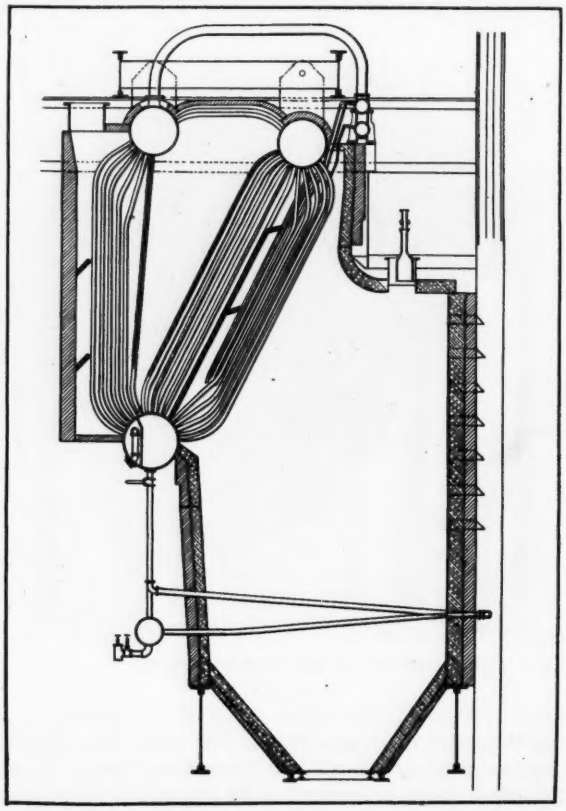


FIG. 22. LADD THREE DRUM BOILER SET FOR POWDERED FUEL BURNING

Baffling is horizontal and placed to guide the gases parallel with the tubes. Steam connections are made to the top of each upper drum and brought together by pipe connections to a tee fitting placed centrally with respect to the furnace depth. Feed connections are made to both upper drums. The lower drums are supported on saddles which rest on a structural steel framework.

MURRAY IRON WORKS COMPANY

Longitudinal drum water-tube boilers, Fig. 24, as built by the Murray Iron Works, consist of one or two drums with front and rear steel plate headers of equal

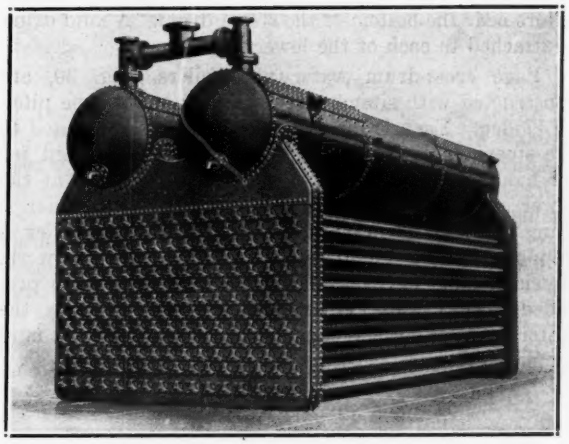


FIG. 24. MANIFOLD CONNECTS THE TWO MURRAY BOILER DRUMS

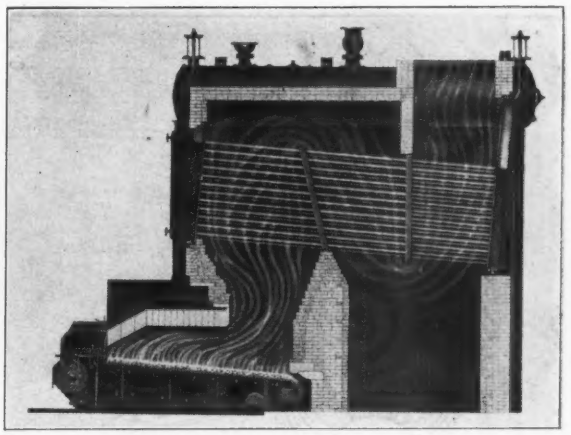


FIG. 26. DRUMS ARE HORIZONTAL IN O'BRIEN VERTICALLY BAFFLED BOILERS

depth, with wrought tubes connecting the headers. Both the drums and the tubes are inclined to the rear. The headers are of the rectangular box form, and are connected to the drums through openings made by cutting out a number of smaller oblong openings, and leaving a sufficient amount of the original material to act as stays. The staybolts are hollow to allow the insertion of blowers.

Each tube is provided with its own oval forged steel handhole plate with gasket, bolt, and crab, or if preferred Key patent handhole plates can be used.

Manholes are provided in the drums for inspection, cleaning, and repairing. These boilers are fed through the front header and an internal mud drum, which is provided with blowoff pipe. At the bottom of the rear header is a perforated locomotive type blowoff pipe for removing the sediment.

John O'Brien Boiler Works Company

Water-tube boilers as manufactured by the John O'Brien Boiler Works Co. are of three general types: longitudinal drum, cross drum and vertical bent tube. The first named type follows two distinct designs, in one of which the drum is parallel to the tubes, as shown in Fig. 25, and in the other the drum is level and the tubes inclined, as shown in Fig. 26. In longitudinal drum boilers a nest of tubes, uniformly spaced in straight horizontal rows and staggered vertical rows, are rolled into the tube sheets of box type headers. Forged steel throat braces are riveted inside the shell at the point where the header and shell are riveted together.

In the header construction, the tube and handhole sheets are flanged, the wrapper then is a plain strap. A steam baffle is placed opposite the up-take header. Feed water enters the drum head and is discharged into an internal mud drum. Both ends of the boilers are suspended from steel frame-work.

O'Brien cross drum boilers, shown by Fig. 27, consist of an inclined tube nest connected to box type headers each of which is connected by two rows of tubes to a cross-drum placed above and slightly forward of the down-take header. Headers are of two-piece construction, that is both the tube and handhole sheets are flanged, which brings all rivet heads on the outside. Feed water enters a mud pan located in the drum and both steam baffles and dry pipe are provided. The boilers are slung at both ends from a structural steel frame.

Two drums, one placed directly above the other, and connected by three nests of vertical bent tubes, are the essential features of the O'Brien vertical boiler, illustrated in Fig. 28. The upper or steam drum is provided with steam baffles and a dry pipe. The lower or mud

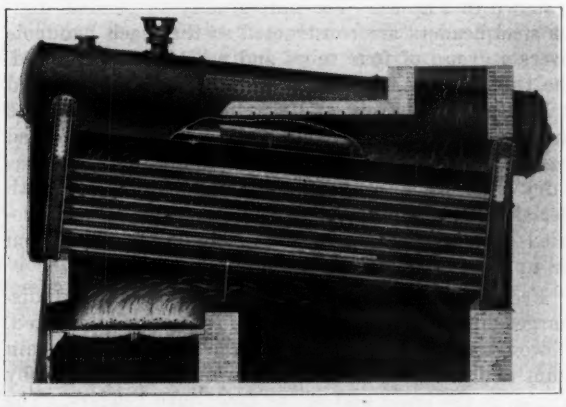


FIG. 25. TUBES AND DRUMS ARE PARALLEL IN O'BRIEN HORIZONTALLY BAFFLED BOILERS

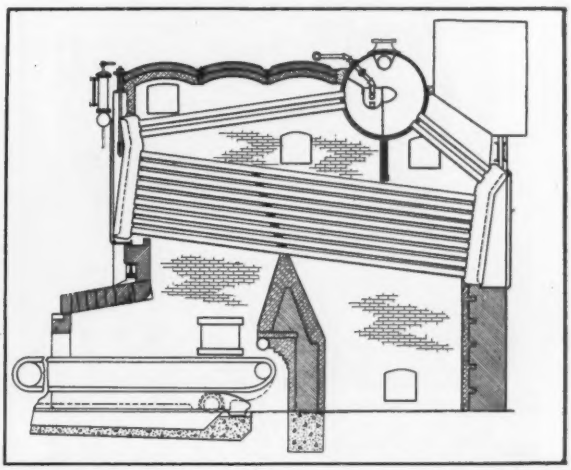


FIG. 27. SECTIONAL ELEVATION OF THE O'BRIEN CROSS DRUM BOILER

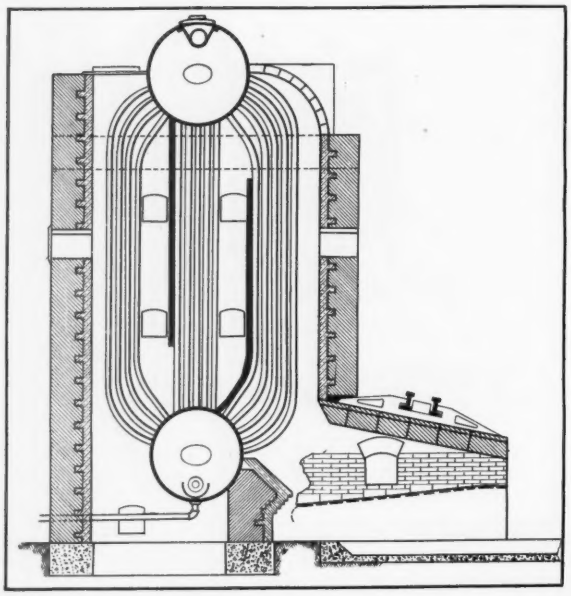


FIG. 28. O'BRIEN VERTICAL WATER TUBE BOILER

drum is equipped with a feed water connection, internal mud pan and blowoff connections. The weight of the boiler is carried on cast saddles which rest on a structural steel frame. Baffles are vertical to provide three gas passes parallel to the tubes.

PAGE BOILER CO.

Sectional water-tube boilers as constructed by the Page Boiler Co. are unique in that they consist of a series of vertical sections each having an independent water intake and an outlet to a steam drum placed crosswise of the tubes; this is shown by Fig. 29. Half of the sections are arranged diagonally across the boiler in one direction, and the other half in the opposite direction, alternately across the entire width of the boiler. The tubes are inclined and accessible at each end through handholes. Steam is taken through a dry pipe and feed

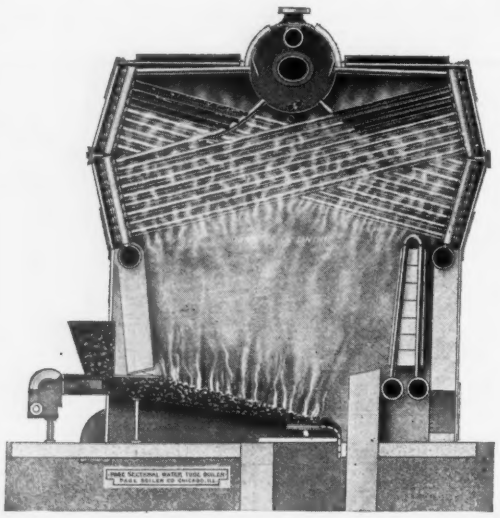


FIG. 29. SIDE VIEW OF THE PAGE SECTIONAL WATER TUBE BOILER

enters near the bottom of the steam drum. A mud drum is attached to each of the lower headers.

Page cross-drum water-tube boilers, Fig. 30, are constructed with sinuous steel headers and a tube pitch of 17 deg. Each front and rear header is connected to the steam drum by two tubes. Key caps are used for all handholes except the master handhole plate at the lower end of each header section. The front header is hung from steel work and the rear end of the boiler is supported on a foundation built on structural work. Steam-circulating baffle plates and a dry pipe are provided. Feed water enters the drum head below the water line. Blowoff connections are made to the mud drum which is attached to the down-take header.

SPRINGFIELD BOILER CO.

Water-tube boilers as manufactured by the Springfield Boiler Co. are of the cross-drum straight tube type,

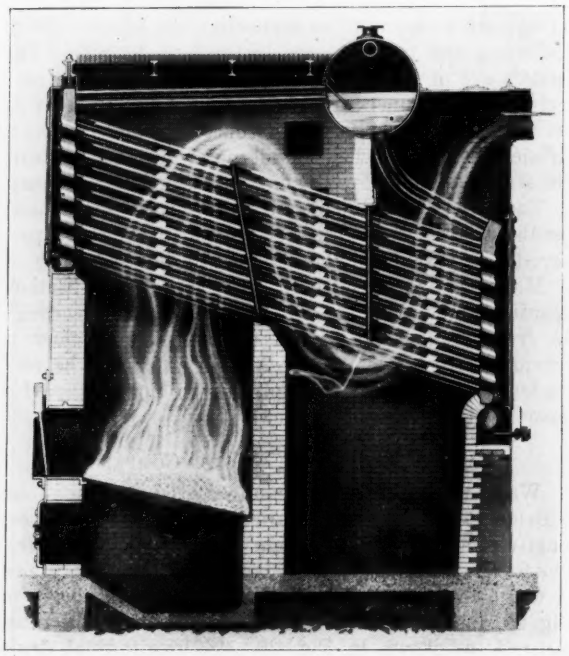


FIG. 30. PAGE CROSS DRUM BOILER SET FOR HAND FIRING

as shown in Fig. 31. The individually suspended sinuous steel headers are constructed so that each handhole covers a group of four tubes and no staybolts are used. The tube groups, four each, are staggered and pitched at 15 deg. Each front and rear header is connected to the drum by four tubes. The drum is fitted with forged nozzles for steam and safety valve connections, and has a dry pipe which is perforated and constructed with special baffle plate wings. The steam drum is also provided with a baffle opposite the discharge tubes from the up-take headers.

Feed water enters the side of the drum and discharges into the mud box which is partly submerged. Blowoff connections are made to the mud box, the main drum and the steel mud drum which is connected by nipples to the lower end of the down-take headers. The boiler is suspended from the up-take header and the down-take header rests on a ball bearing supported on

masonry independent of the setting walls. Standard boilers are of single deck—double deck—and drop tube design.

Union Iron Works

Longitudinal-drum water-tube boilers, as shown in Fig. 32, are built by the Union Iron Works, in which a special corrugated flange is used to connect the drums to the headers, thus giving liberal throat area and flexibility. The tubes are staggered and rolled into box headers. Each tube end is covered by an inside handhole plate which may be withdrawn through the hole which it covers.

Feed water is brought in at the front end of the drum and carried through to the rear in an internal feed pipe which discharges into the purifying chamber. This purifier is at the rear end of the drum, out of the gas passage area and away from circulation. The precipitate is discharged through a blowoff connection. A surface blowoff is provided from this chamber, also

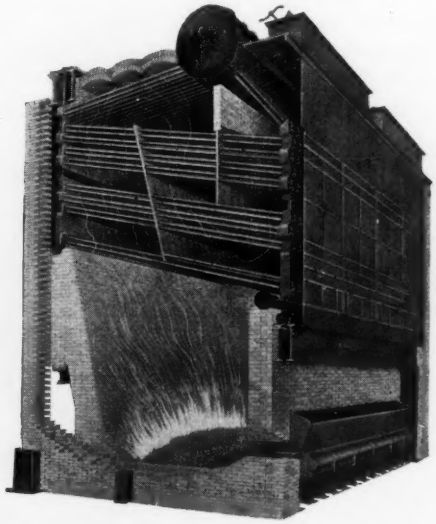


FIG. 31. SPRINGFIELD BOILER OF DOUBLE DECK AND DROP TUBE CONSTRUCTION

blowoff connections are made to the bottom of the down-take header. This boiler is suspended by loops placed under the front end of the drum, the down-take header resting on wall plates and roller supports, or it can be supported by gallows frame if preferred.

Union Iron Works cross-drum boilers are built with special deflector baffles and dry pipe arrangement as well as double rows of circulating tubes. The patented feed water purifier and pre-heater are also used.

Henry Vogt Machine Co.

Water-tube boilers, shown in Fig. 33, built by the Henry Vogt Machine Co., are of the inclined straight tube type. The steam drums are longitudinal; the tube headers are cylindrical and have no staybolts. Flat bosses are pressed into the header shells so that the tubes are perpendicular to the surface of the sheets. The two parts of each twin drum are riveted together throughout the length of the flat portions of the two shells. Large water circulating openings are cut through this interior flat section of the twin drum.

FIG. 32. UNION IRON WORKS BOILER HAS FLEXIBLE HEADER CONNECTIONS

Feed water is introduced into the steam drums near the rear; during its passage down the bank of vertical tubes, it is heated to the boiling temperature. From the mud drum the water and steam flow back and forth through the succeeding banks of tubes and enter the steam drums from the front single drum through large throat connections.

Gas travel is long and counter current to the circulation of the water. Extremely large steam storage space is provided for rapid and wide fluctuations in load.

To facilitate cleaning, the front tube headers have handholes opposite the tubes. The handhole covers are made tight with gaskets. The baffle tile all rest upon the banks of tubes. Expansion and contraction do not cause stresses as all parts of the boiler are free to adjust themselves relative to each other.

The Wickes Boiler Company

Wickes vertical water-tube boilers, shown by Fig. 34, have two cylinders of the same diameters but differing

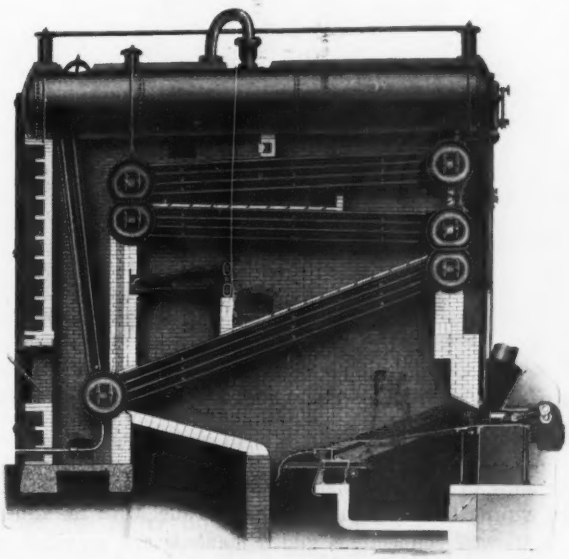


FIG. 33. HENRY VOGT MACHING CO. STRAIGHT TUBE BOILER

in their height and arrangement of convexed heads. In both drums the tube sheet and convexed head are joined by heavy braces. The top or steam cylinder is the longer, its convexed head being provided with a manhole, handholes, and connections for steam and safety valves. Feed water connection may be made near the

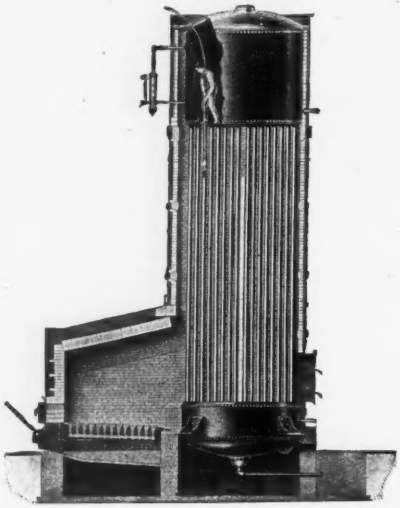


FIG. 34. ELEVATION OF THE WICKES VERTICAL WATER TUBE BOILER

lower end of this shell or into the mud drum, which is located directly beneath the steam drum and connected to it by vertical straight tubes which are arranged in parallel rows. The tube nest is divided into two sections by a tile baffle extending across the boiler at the drum center. This baffle rests on the lower drum and

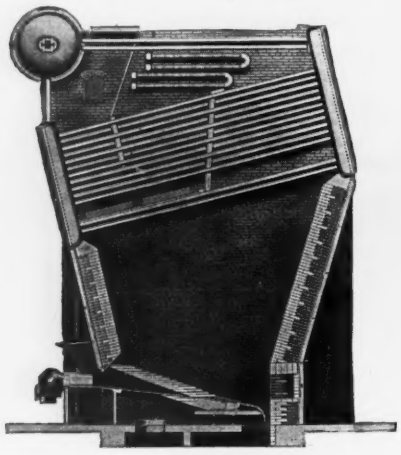


FIG. 35. SECTIONAL VIEW OF THE WICKES CROSS DRUM BOILER

extends to within a short distance of the upper drum, providing two long gas passages parallel with the tubes.

Blowoff connections and a manhole are provided in the convexed head of the mud drum. This boiler is supported by four heavy lugs riveted to the mud drum.

Horizontal cross-drum water-tube boilers, shown in Fig. 35, also manufactured by The Wickes Boiler Co., consist of two headers connected by straight tubes which are set at an angle of 15 deg. The up-take header is connected to a cross drum by two rows of horizontal tubes. The lower or down-take header is connected to the drum by a single row of vertical tubes. The up-take header is of less depth than the down-take header.

Header construction is interesting in that no wrapper section is used, the tube sheet being flanged so there is but one riveted joint at its connection to the handhole sheet. Oval handholes are spaced at intervals to facilitate the placement of the round handhole plates. Feed water enters the drum through a perforated internal feed pipe open at the ends. The gas baffles are moulded and so arranged as to compel the gas to flow across the tubes.

Kingsford Foundry & Machine Works

Kingsford Foundry & Machine Works build longitudinal and cross-drum types of water-tube boilers. In both types, the sectional sinuous headers are vertical. Their connection to longitudinal drums, as shown in Fig. 36, is by means of circulating tubes and cross boxes

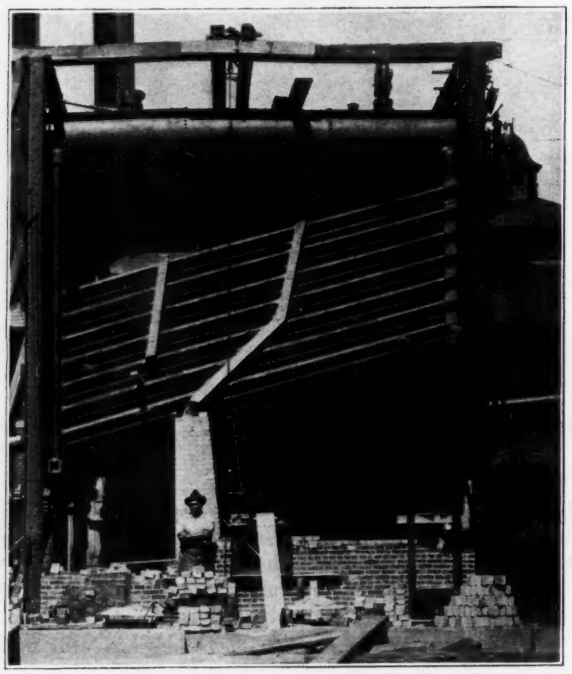
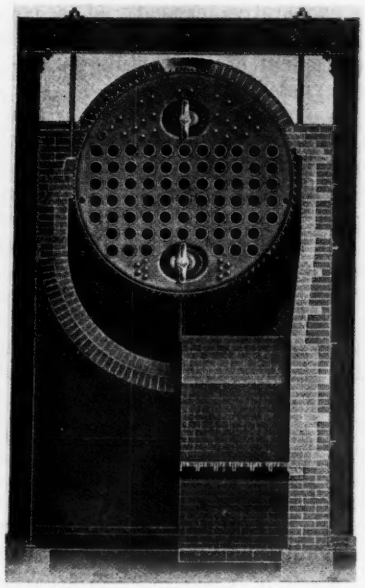


FIG. 36. CONSTRUCTION VIEW OF KINGSFORD FOUNDRY & MACHINE WORKS BOILER

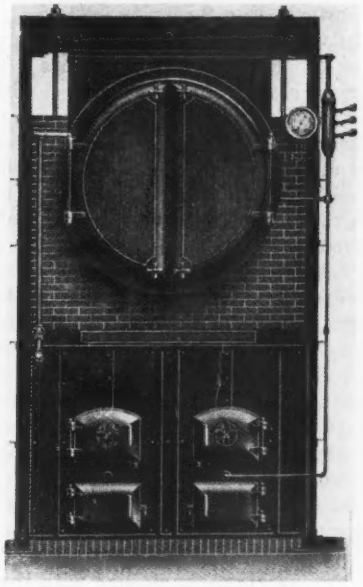
riveted to the drums. In the cross-drum type a row of horizontal tubes ties together the front header and the drum, while circulating tubes connect the top of the rear header and the drum which is located directly above.

Additional circulating tubes extend from the drum past the rear header and are expanded into the mud drum, which is connected by nipples to the lower ends of the rear or down-take header. This feature is incorporated to insure an adequate amount of water to the lower tubes when operating at the higher ratings.



Horizontal Return Tubular Boilers

DUE TO THE INFLUENCE OF STANDARDIZATION THE SELECTION OF A HORIZONTAL RETURN TUBULAR BOILER WILL DEPEND LARGELY UPON BOILER SHOP PRACTICE



ADVANTAGES claimed for the return tubular boiler are: that it has great evaporative capacity in proportion to its size and weight, that the water content is divided into thin currents which circulate in contact with a large number of tubes, and that for a stated proportion of heating surface it is the least expensive of all boilers which have good evaporative efficiency. This type of boiler is not ordinarily built for pressures over 200 lb. per sq. in. or in sizes above 200 hp.

Tube Arrangement Must Not Interfere with Circulation

Boiler tube spacing is governed primarily by the strength of the tube sheet which will remain after the tube holes have been cut and tube arrangement by those general requirements of circulation and gas passage which directly affect the boiler as a steamer. The location of the top row of tubes is also important because it establishes the water line and therefore proportions the steam and water space.

Besides the strength of the ligament remaining between the tube holes, the factors of water circulation and shop practice must be taken into account when locating one tube with respect to another. Shop practice requires that not less than 1 in. shall be left between adjacent tubes, and in order to establish definite paths of circulation it is customary to have a space of not less than 2 in. between the vertical rows of tubes nearest the center and not less than 2½ in. between the shell and the nearest tube.

Ordinarily tubes are spaced in straight horizontal and vertical rows. The staggered tube layout is not recommended for fire-tube boilers because it restricts circulation and seriously interferes with internal inspection and cleaning. A staggered tube layout is used, however, where the tubes are so arranged that the horizontal rows are staggered but the vertical paths of circulation are unobstructed.

In Fig. 1 is shown a typical layout for the front head of a 72-in. boiler in which the top row of 3½-in. tubes is located 5 in. above the center line of the shell. In practice the center line of the top row of tubes varies from 5 to 12 in. above the center line of the boiler. The establishment of this dimension does not follow any fixed rule but is determined for a given diameter of shell by the number and size of tubes which it is desired to use. Tube spacing at the lower part of the

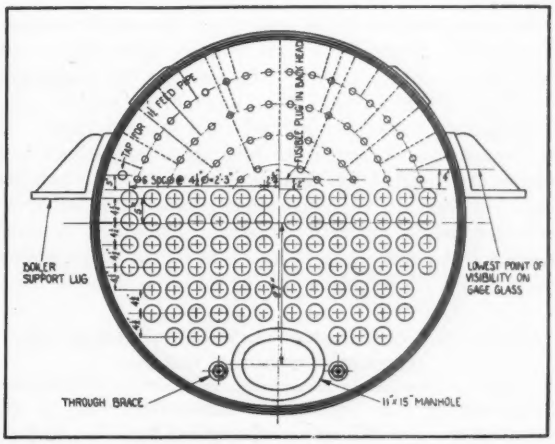


FIG. 1. TYPICAL LAYOUT OF A FRONT HEAD TUBE SHEET

head for boilers 48 in. in diameter and over is partially determined by the location of an 11 by 15-in. manhole which is placed below the tubes. Boilers smaller than 48 in. in diameter should have either a manhole or a handhole below the tubes.

Front Ends Are of Two Common Forms

In horizontal return-tubular boilers, the waste products of combustion, after they have traveled forward through the boiler tubes, must be removed. This is accomplished by the "front end," a smoke box that gathers up the waste gas as it leaves the tubes and discharges it to the breeching. Front ends are of two

common forms, the flush front and the extended front, as shown in Fig. 2.

In the flush front setting the flue doors are directly above the fire and ash pit doors. There is no overhanging obstruction to interfere with the fireman in his work of tending fires or cleaning the ash pit. The boiler proper may be of the plain shell type or it may have an extension on the front end of the shell. This extension, if supplied, would correspond, approximately, with the thickness of the front wall of the setting.

Ordinarily the plain shell boiler will be used with the flush front type of setting and the boiler may be either suspended from a frame or the smaller sizes of boilers may be arranged with lugs for support on the setting walls. The latter arrangement will sometimes be preferred, where permissible, for the reason that the front lugs can be anchored, thus controlling expansion towards the rear of the setting and so insuring the maintenance of a tighter joint between the shell and the front wall.

In this type of setting the smoke box is formed by leaving a space between the cast-iron setting front and the front tube sheet, by locating the outside of the tube sheet on an approximate line with the inside face of the front wall. To seal the joint at this front effectively, it is customary to corbel the front wall so that the brickwork overlaps the shell for a distance of from 3 to 6 in. This joint may be packed with asbestos fibre as a further insurance against shortcircuiting the furnace gases into the smoke box. The brickwork of the front wall is carried up, with the shell as a template, to the centerline of the boiler and from that point it may be straight or it may be corbeled slightly to meet the dimensions of the smoke connection to the breeching.

In the extended front end type, the smoke connection projects beyond the outside face of the boiler setting. This extension may be formed by the projection of the shell beyond the front head or it may be cast integral with the upper half of the cast-iron front. In the former case a cast-iron door ring and smoke connection are fitted to the shell extension and cast-iron flue doors are then fitted to the ring. Some extended front ends are made entirely of steel. Standard practice allows a front end depth of about 14 in. for 42-in. boilers and a depth of about 18 in. for 84-in. boilers.

DIMENSIONS OF UPTAKES OR SMOKE-OPENINGS FOR HORIZONTAL TUBULAR BOILERS

Diameter of Boiler	Uptake or Smoke Opening		
	Width	Length	Area (sq. in.)
54″	10″	3′-4″	400
60″	10″	4′-6″	540
66″	12″	4′-6″	648
72″	14″	5′-0″	840
78″	14½″	5′-6″	957
84″	17″	6′-0″	1224

From The Hartford Steam Boiler I. & I. Co.

Evaporative Capacity of a Boiler Depends Upon the Heating Surface

Parts or a boiler shell or tubes which are covered by water on the one side and exposed to the hot gas or radiation on the other side constitute the heating surface of a boiler. Any surface which has steam on one side and hot gas on the other is termed superheating surface. The surface in contact with gas is used when figuring the evaporative capacity of a boiler, because the A. S. M. E. Boiler Test Code Committee recommends that the extent of the heating surface be measured on the side exposed to the gas.

To figure the area of the heating surface of a horizontal return-tubular boiler, take one-half the area of the shell, plus two-thirds the area of each head, after deducting the tube hole areas, and to these add the surface of the tubes. The area of the shell which is considered as heating surface is equal to 1.57 DL, in which D equals the outside diameter of the shell in feet and L equals its length in feet. The heating surface area of the two heads will be equal to 2 ($0.5236\ D^2 - 0.7854\ Nd^2$), in which D is as previously stated, N is the number of tubes and d is the outside diameter of the tubes in feet. The heating surface of the tubes will be $3.141 \times dLN$. The total square feet of heating surface of the boiler will then be $1.57\ DL + 2\ (0.5236\ D^2 - 0.7854\ Nd^2) + 3.141 \times dLN$.

Generally boilers of this type are rated on the basis of 10 sq. ft. of heating surface per boiler horsepower. This means the evaporation of about 3.5 lb. of water

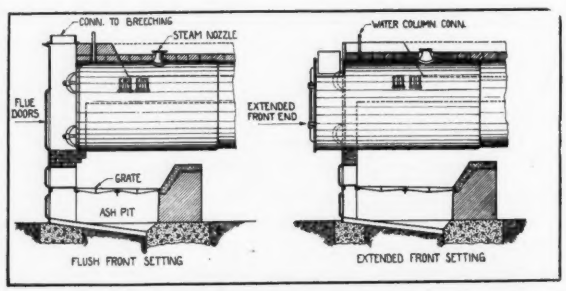


FIG. 2. RETURN TUBULAR BOILERS ARE BUILT WITH FLUSH OR EXTENDED FRONTS

from and at 212 deg. F. per sq. ft. of heating surface per hour. Boilers can be forced so that more water may be evaporated per sq. ft. than is given above and for this reason it is rapidly becoming customary to specify boilers according to their heating surface rather than by the boiler horsepower.

In horizontal return tubular boilers the ratio of tube heating surface to shell is about 5 to 1, but this may be as low as 4 to 1 and it may run as high as 6 to 1, the variation being due to the arrangement and size of tubes. If placed to the best advantage, the heating surface of small tubes, say 3-in., will be greater than that of the next size larger tubes. Small tubes split the gas up into a greater number of streams which is conducive to a higher heat absorption efficiency.

Lack of Water Space Causes Irregular Steaming Action

Steam and water space in a boiler are largely predetermined for the operating engineer. The boiler code of the A. S. M. E. provides that the gage glass shall be set so that its lowest visible part will be 2 in. above the lowest permissible water level, which in the case of h.r.t. boilers would be 4 in. above the top row of tubes. The operator then has this definite relation fixed and he can safely vary the steam or water space only within the limits of the visibility of the water within the gage glass.

If the water and steam capacity of a boiler are too small, its action will be irregular, the steam pressure will vary over wide limits and the water level will be subject to frequent and rapid fluctuation. The steam space in horizontal return-tubular boilers, as commercially constructed, is from one-fourth to one-third of the total volume of the shell. The water content is then the remaining three-fourths or two-thirds, less that space which is occupied by the tubes. These proportions allow from 0.7 to 0.9 cu. ft. of steam space per rated boiler horsepower.

If the water level is carried high in the glass, the boiler will be slow in steaming; on the other hand the greater water content will mean a greater storage of heat which, with fluctuating loads, will be an advantage. A disadvantage arising from a high water level is that the boiler is likely to prime when a bituminous coal fire is stirred up or when there is a sudden demand for steam. This condition is caused by the decreased steam space and the decreased steam disengaging area or water surface. The smaller the area of the water surface, the greater will be the volume of steam which must be liberated per unit of area. This causes a more violent agitation of the water surface with the result of entrainment of water in the steam. A high water level also cuts down on the steam space so that not only will the distance from water surface to steam nozzle be less but the steam velocities within the shell will be higher than if the water were carried at a lower level. The result is that the entrained water is not given time to settle out but is rapidly carried to the steam nozzle and out of the boiler.

As the water level is lowered in a boiler, the water surface is increased because it approaches the center of the boiler where the area would be the largest possible within a cylinder. This increase results in a lower volume of steam to be freed per unit of water surface, so that a steadier water surface is obtained with less tendency for the boiler to prime. In ordinary practice, it will be found that a boiler will maintain a steady water level, produce commercially dry steam and steam quickly, if the water level is maintained from 2 to 4 in. above the bottom of the glass.

Setting the Horizontal Return Tubular Boiler

METHOD OF SUSPENSION, CONSTRUCTION OF SIDE WALLS, TYPE OF BACK ARCH AND THE COVERING ARE IMPORTANT FACTORS IN SETTING BOILERS

IF A horizontal return-tubular boiler is to operate at the best possible efficiency, with freedom from some of the maintenance troubles frequently encountered, considerable thought must be given to the problem of setting the boiler. The method of supporting the boiler from the standpoint of safety and to allow for contraction and expansion; the type of construction for the side walls to reduce radiation losses and infiltration of air; the back arch construction which will reduce maintenance troubles to a minimum and the covering for the top of the boiler which will reduce radiation losses at this point are all factors which enter into the problem.

Due to the increasing size of horizontal return-tubular boilers, which are now built up to 375 hp., the method of support has become somewhat of a problem. With smaller boilers it was a simple matter to rivet two brackets on each side of the boiler and use the side walls as a support. As the weight increased, this method was found to give trouble due to cracking of brickwork and settling of boiler. The independent method of suspension was therefore adopted and was found to be an advantage as it permitted freedom of contraction and expansion.

According to the A. S. M. E. boiler code, boilers larger than 98 in. in diameter must be suspended independently of the setting and at least two pairs of steel supporting lugs must be used on each side, with the lugs of each pair spaced not over 2 in. apart and the load equalized between them. Boilers 14 ft. or more in length, over 54 in. and up to 78 in. in diameter may be supported by the independent suspension or by brackets as desired. In either case, however, the support must be at four points by not less than 8 steel or cast-iron brackets or lugs set in pairs. In the case of boilers under 54 in. diameter, the support must be by not less than two steel or cast-iron brackets or lugs on each side.

Many variations are found in the design of supporting brackets and lugs. Some brackets are made of cast iron, although the tendency seems to be toward the use of pressed steel. As shown in Fig. 1, the brackets sometimes rest on rollers and a steel plate which tends to protect the brickwork when the contraction and expansion movements take place. Lugs used with the suspended method of support are usually pressed steel, cast iron or forgings and are made in a number of shapes one of which is shown in Fig. 1.

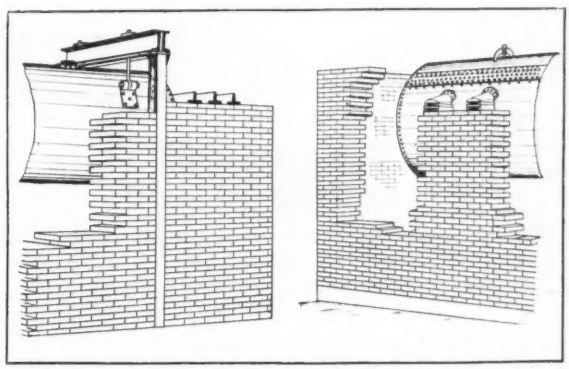


FIG. 1. BOILERS MAY BE SUPPORTED BY THE SIDE WALLS OR SUSPENDED FROM I-BEAMS

In erecting the boiler, the usual method followed is to block it up with timbers in such a way that the supports will not interfere with laying the brickwork, or if the boiler is to be independently suspended, with erecting the supporting columns and I-beams. After the work has proceeded to the point where the boiler is self supporting, the blocking is removed.

Several types of wall construction are used. In Fig. 2, four schemes are shown which are recommended

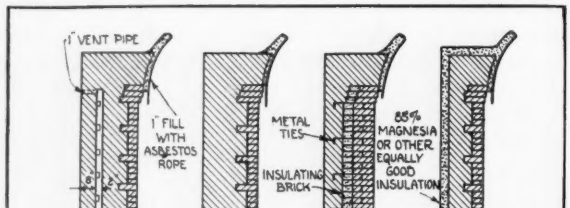


FIG. 2. SIDE WALL DESIGN DEPENDS PARTLY ON THE HEAT INSULATION DESIRED

by the Hartford Steam Boiler Inspection & Insurance Co.

While the plain wall as shown in B of Fig. 2 is the least expensive, it has the disadvantage that any cracks which may develop are likely to extend clear through the wall, thus increasing the probability of air leaks with consequent decreased furnace efficiency. In order to overcome this difficulty, the double wall construction as shown in A is sometimes used.

With this construction, cracks occur principally in the inner wall, leaving the outer wall intact. At one time, this air space was considered to be of some value as a heat insulator, but tests have not shown this to be the case, and where this construction is used the space is better filled with ashes, sand or other loose material.

In the majority of cases, the walls are of common brick, lined with fire brick where the temperature is high. Of recent years, however, there has been a tendency toward the use of a heat-insulating material between the common brick and the fire brick. One form of construction, as shown in C of Fig. 2, uses insulating brick. As the insulating brick have little mechanical strength, it is advisable to use metal ties, as shown, to bond the inner fire-brick section to the common brick on the outside. It is also advisable to use a uniform thickness of 9 in. for the fire-brick lining instead of the 4½-in. lining with header courses, as shown for the other types.

Type D shown in Fig. 2 is similar to type A except that a steel casing is substituted for the outer wall and the air space is filled with magnesia or other insulating material. This setting is more costly than any of the others, but the heat radiation loss is reduced to a minimum and the steel casing prevents air leakage through the setting.

All of the sections shown in Fig. 2 are intended to apply to the side walls at the rear of the bridge wall. For the furnace section in front of the bridge wall, the walls should be battered from the grate level to the closing-in line near the middle of the boiler shell. A batter of 6 in. in this height is recommended.

In some cases the insulation is omitted at this point as it has been found that, where the furnace is run at high rating, the fire brick will fail unless there is some radiation to keep the wall temperature down. Another method is to leave an air space between the fire brick and the outer wall through which the combustion air is drawn. This serves to keep the temperature of the fire brick down and at the same time preheats the air fed to the furnace, thus aiding combustion and increasing efficiency by reducing radiation losses.

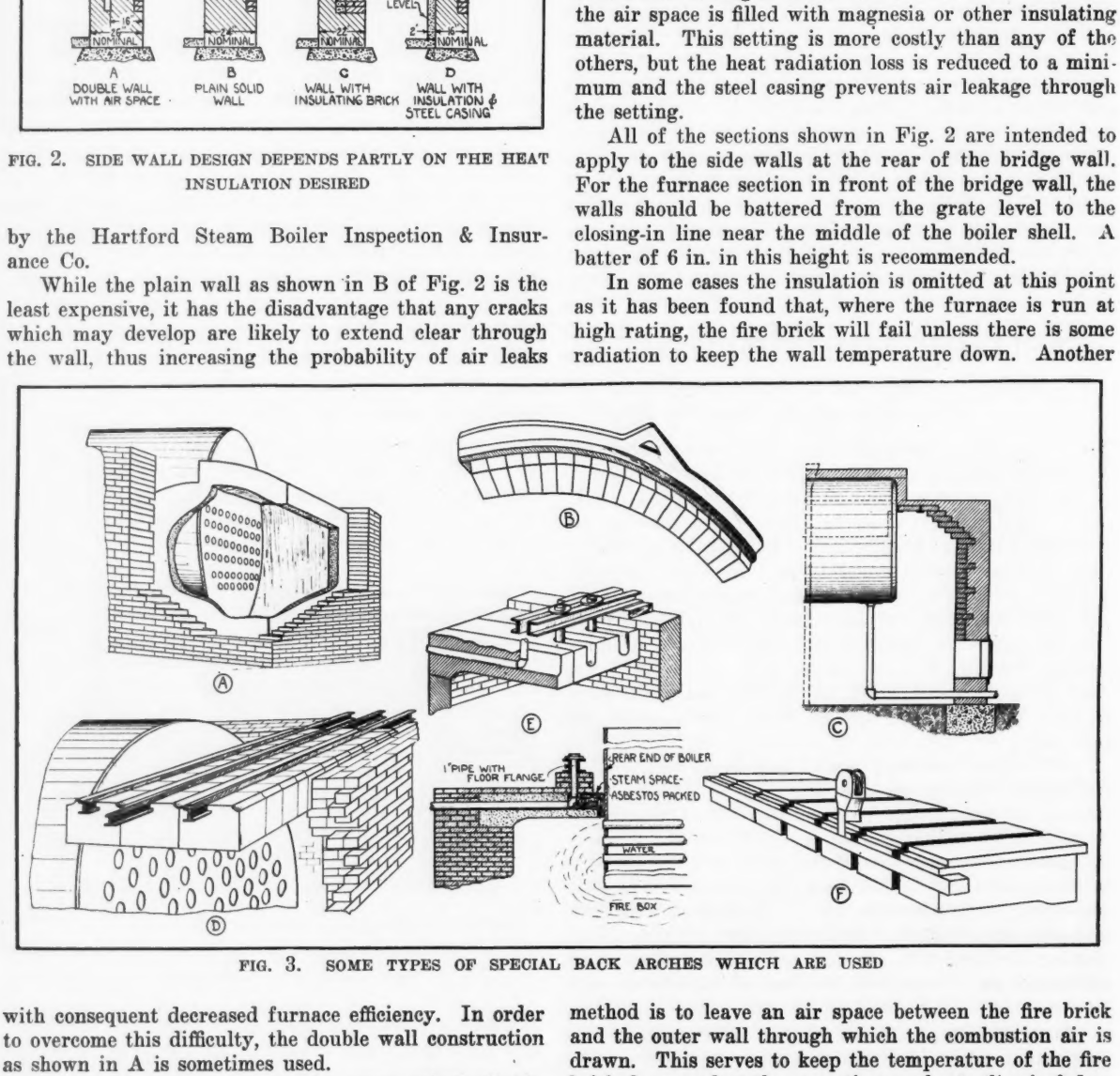


FIG. 3. SOME TYPES OF SPECIAL BACK ARCHES WHICH ARE USED

This general scheme has also been applied to the extended setting where an ignition arch is used. In this case the air is drawn through an opening left between the arch and the roof of the extended setting which is a modification of the Dutch oven type of furnace.

Another detail of the horizontal return-tubular boiler setting which has been given much attention by designers during the past few years is the back arch.

This is difficult to construct of ordinary fire brick. It should be gas-tight and at the same time it must allow for the expansion and contraction of the boiler. If the arch rests against the head of the boiler, it will soon disintegrate; while, if supported by irons which are in contact with the hot gases, the supporting irons are liable to warp or burn out. Further, the arch should be flat across the boiler head to protect the sheet immediately above the water line. It should also be nearly flat from front to rear in order to give sufficient room for the use of expanding tools on the tubes without removing the arch.

In Fig 3-C is shown a typical construction of a back arch using fire brick and T-bars and angles for supporting members. While this form of construction has certain disadvantages, it has been extensively used in the past, but has been almost superseded in recent years by other forms of construction.

One scheme which is employed is the use of the stuffed rear arch bar as shown in Fig. 3-B. This is a casting which is arranged for holding special fire brick shapes, the back arch being made up of a number of these bars. With this form of construction, it is possible to remove a section of the arch and replace any brick which have failed.

Another form of back arch construction, known as the monolithic type, is made up of a plastic refractory material which can be erected by the use of forms. While soft, the material is supported by a light wooden form; a slow fire under the boiler dries out the material sufficiently to make it self supporting, then a normal fire burns out the forms and completes the hardening of the arch. As the boiler expands during heating, the plastic material is pushed back before it finally sets, and when the boiler cools down and contracts a small space is left between the monolithic arch and the tube sheet, but since this is closed up in normal operation, it should not be packed with asbestos or any other material. This type of construction is shown in Fig. 3-A.

Another development in back arches is the use of special tile shapes which are suspended by small I-beams as shown in Fig. 3-D. Since the supporting members are protected by the tile, there is no danger of warping or burning. Should one of the tile fail, it can be replaced by lifting out the entire row and slipping another one on the I-beam.

Another arch using this form of construction is shown in Fig. 3-F. The arch is formed by a row of special blocks ship-lapped and cemented together to cover completely the back combustion chamber, and curved on the under surfaces to deflect the gases toward the flues. The rear end of each block rests on the rear boiler wall and the front end is grooved to fit over and hang upon a 2-in. square iron bar which rests upon the side boiler walls. When the arch is over 6 ft. wide, it is further supported at the center by an overhead suspension connected to clevices. At the front, the bar is protected by asbestos and at the top, bottom and back by the arch blocks.

Infiltration of air was previously mentioned as one cause for low boiler efficiency. In case of a setting erected along modern lines, with a steel casing or a covering of some one of the plastic materials now supplied for such work, there is little likelihood of air leakage.

In the case of old settings, there is usually opportunity to reduce the radiation losses and at the same time close up the air leaks by using some form of covering. One method which has been used by the Illinois Traction Co. is illustrated in Fig. 4. Wire loops, projecting about 1¼ in., are imbedded between the bricks, which are painted with several coats of tar and asbestos wool and then covered with a thick layer of asbestos paste. Chicken wire mesh is placed over this and fastened to the loops, followed by a second layer of asbestos and 10 oz. duck painted with asphalt varnish, the whole insulation being about 2 in. thick.

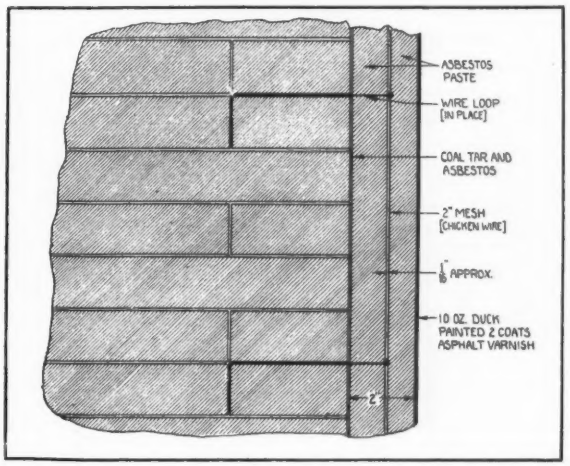


FIG. 4. COVERING FOR SETTING WHICH REDUCES RADIATION AND AIR INFILTRATION

For the top of the boiler, various coverings are used for heat insulation purposes, such as sand, brick, mineral wool, asbestos and concrete. Where an insulating brick is used between the fire brick and the outer wall, this is frequently continued over the boiler and covered with asbestos paste and heavy duck. Some companies have used a concrete covering made up of a 1:2:4 mixture of cement, sand and gravel.

VISIBLE SMOKE is composed chiefly of fine particles of carbon and tar. When seen under the microscope, the particles are shown to be really clusters of smaller particles, each about 0.000,002 in. in diameter. Because of their small size these clusters are carried easily by even the slowest moving gas stream. These particles when glowing are the cause of the visibility of the furnace flame. The actual carbon in dense smoke amounts to about 1 per cent of the carbon in the coal or fuel oil, and is not in itself the main source of loss. It is generally accompanied, however, by non-visible but highly combustible gases, the loss of which may amount to 10 per cent. High CO and smoke in the stack gases represent high losses, not so much because of the losses in these two themselves but because they indicate the presence of unburned hydro-carbons. At the same time smokeless combustion does not necessarily indicate perfect combustion. It is a simple matter to burn coal or oil smokelessly, but to burn it smokelessly and without loss is a difficult matter. The best results and the highest sustained efficiency of combustion are being attained when there is a slight feather or whisp of hazy smoke at the stack.

Adaptability of Vertical Tubular Boilers

THIS TYPE OF BOILER IS SUITED FOR INSTALLATIONS WHERE COMPACTNESS AND LOW FIRST COST ARE OF PRIME IMPORTANCE

IN SELECTING a boiler to meet any particular set of requirements, there are certain questions of design and construction that must be given careful consideration, if the greatest possible ultimate economy in carrying charges, maintenance and fuel is to result. Where relatively small capacity, compactness, and low first cost are of prime importance, and where the ground space is limited by reason of high rental charges, the vertical tubular type boiler is well suited.

Vertical tubular boilers are seldom built in sizes exceeding 100 or 125 hp. and it is not possible to operate them much above rating for the reason that the grate cannot be made large enough to burn efficiently the requisite amount of coal. All such boilers are internally fired and for this reason the size of the grate is definitely limited by the size of the boiler.

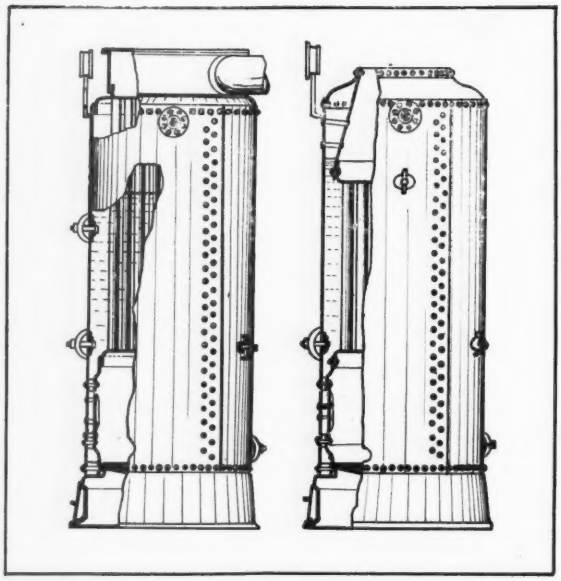


FIG. 1. EXPOSED TUBE VERTICAL TUBULAR BOILER (LEFT) HAS CONSIDERABLE SUPERHEATING SURFACE

FIG. 2. SUBMERGED TUBE BOILER HAS EXCEEDINGLY SMALL STEAM DISENGAGING SURFACE

Fundamentally a vertical tubular boiler consists of a vertical cylindrical shell in which are arranged a nest of vertical tubes and a fire box in the lower section. The fire box is surrounded by a water leg and the crown sheet forms the lower tube sheet. The products of combustion pass directly up through the tubes and out the stack. The diameter of the combustion chamber is necessarily limited by that of the boiler as a whole and the distance from the grate to the crown sheet is usually small. In no case, however, even in the smallest units, is it less than 24 in. In the larger size units, this dimension is increased; but scarcely ever is it sufficient to permit of smokeless combustion with ordinary bituminous coal.

Mechanically, the construction of this type boiler is quite simple and for the amount of heating surface available the over-all dimensions are small. For this reason, the initial cost per rated horsepower is small as compared with either the return-tubular or water-tube boiler. The floor space necessary is about equal to that required for the grate only, of any other type boiler of like capacity and it is for this reason that these boilers will frequently be found installed in congested districts where real estate values are high. Their characteristic compactness makes them especially adaptable for use in portable or semi-portable installations such as cranes, trench diggers, and derricks.

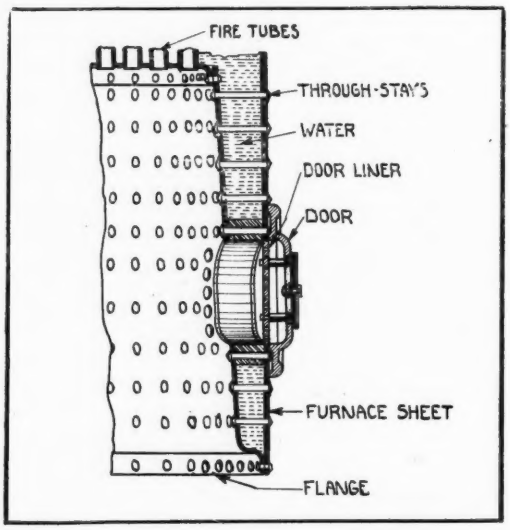


FIG. 3. DETAIL OF WATER LEG OF A SMALL CAPACITY VERTICAL TUBULAR BOILER

One advantageous feature of the compact construction is the relatively small water capacity per unit of heating surface. This makes for quick steaming ability, which may be of importance for certain classes of work. This same characteristic, however, means a small heat capacity in the water which results in widely fluctuating pressures with ordinary load changes.

EXPOSED-TUBE BOILER GENERATES SUPERHEATED STEAM

Tubes are arranged vertically directly over the grate and in the smaller sized units are quite short. The gases of combustion traverse them only once, consequently the temperature drop is low and the final flue gas temperature high, too high for good economy or efficiency. This is especially true at higher ratings; more fuel is burned, greater quantities of furnace gases have to be handled, their velocity through the tubes is consequently greater, the heat absorption is less and the flue gas temperature is higher, reaching a point at times where it becomes a source of danger to exposed surfaces above the water line.

In general, there are two types of vertical tubular boilers, the exposed and the submerged tube. In the first case, the water level is carried somewhat below the upper tube sheet and the upper portion of the tubes is

exposed only to steam, forming, therefore, a superheating surface. This type is shown in part cross section in Fig. 1. In the submerged-tube boiler, shown in Fig. 2, the water level is carried above the tube sheet, the tubes as well as the tube sheet are completely submerged and there is practically no superheating surface.

For most purposes where a vertical tubular boiler can be used to advantage, the exposed-tube type meets with the greater favor. Owing to the position of the water level there is an appreciable amount of superheat, from 20 to 40 deg. depending on the construction of the unit. This is effective in reducing the condensation in the steam header and the initial condensation in the engine which results in a higher over-all plant efficiency than would otherwise be obtained. It also has more steam disengaging surface than the submerged-tube, which decreases the tendency to prime, an objectionable feature in this general type. What priming does occur is taken care of by the superheating elements. For a given amount of tube surface, the water reserve of the exposed-tube type is relatively small and for this reason variations in load cause wide fluctuations in pressure.

The superheating surface reduces the length of tube in contact with water which, of course, reduces the total heat transmission for a given total length of tube, consequently the flue gas temperature is materially increased.

Vertical tubular boilers are at a disadvantage as to accessibility for inspection and cleaning. Except in one or two cases where the boiler is designed with this point in mind, there is not room between the tubes and shell to accommodate a man on the inside, hence all cleaning must be done from the outside through hand holes advantageously placed. The American Society of Mechanical Engineers boiler code requires, on boilers of this type, seven handholes, three in the shell at the line of the crown sheet, one in the shell at the water line, and three in the shell in the lower part of the water leg. These are scarcely sufficient to permit of the complete removal of any scale that may form.

Submerged-Tube Boilers Have Larger Water Capacity

Submerged-tube vertical boilers differ from the exposed-tube type only in that the water level is carried above the upper tube sheet. With this arrangement, the steam disengaging surface is greatly reduced and the water reserve increased. The result is that for a given rate of steaming, there is a greater opportunity for priming and, when priming does occur, there is practically no superheating effect to counteract it. As a consequence, the steam delivered is always wet even at moderate loads.

The increased water capacity per unit of heating surface available in this form of construction permits of greater flexibility of load without undesirable steam pressure fluctuations. This has a tendency also to reduce spasmodic priming, which serves to compensate in some measure for the effect of the small steam disengaging surface.

Mechanically the only difference between the two types of boilers is that, in the submerged-tube type the smoke box is subjected to boiler pressure, consequently must be more substantially constructed than in the exposed-tube boiler. Ordinarily this portion of the boiler is in the shape of a truncated cone, made to fit the tube sheet at the bottom and the stack at the top. This cone is subjected to pressure on the convex side and is therefore stayed with screwed staybolts from the outer shell.

Owing to the possibility of the collection of scale on the under side of the upper tube crown sheet and to the consequent liability to burn this sheet, boiler codes specify that boilers of this type shall be provided with two additional handholes at the line of the upper tube sheet in order that cleaning and inspection of this member be possible. Where small vertical boilers are used for portable service in the open and where they are operated only occasionally, care should be taken to see that the top of the stack is protected from the weather. If the stack is left open at the top, rain water will collect on the soot-incrusted tube sheet, and cause serious corrosion.

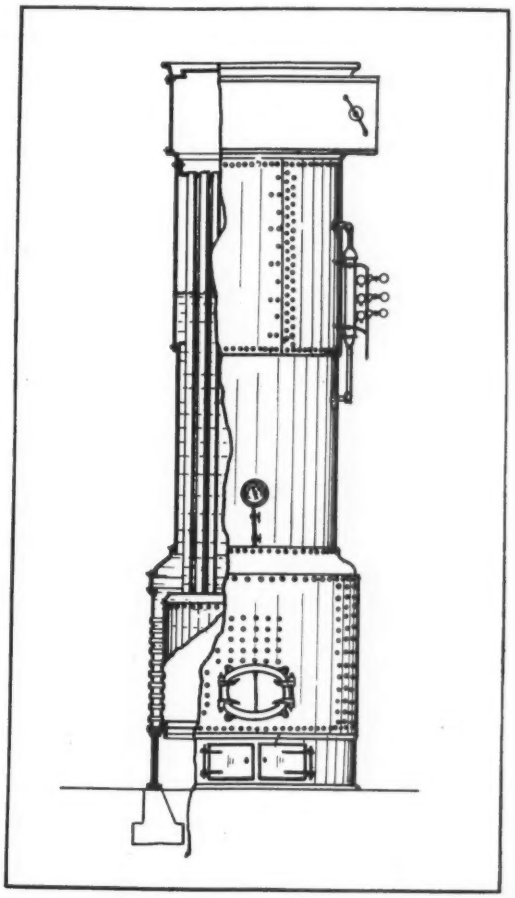


FIG. 4. MANNING TYPE VERTICAL TUBULAR BOILER PROVIDES FOR A LARGER COMBUSTION SPACE

Details of Construction

Vertical tubular boilers, being of the internally fired type, must have some method of cooling the furnace walls. This is the primary function of the water leg. A detailed section indicating in general the type of construction employed is shown in Fig. 3. The position of the grate is not indicated in this sketch, but it is slightly (a matter of 3 or 4 in.) above the lowest water-cooled surface. The water leg extends this distance below the fire line to allow for the accumulation of sediment where it will not be a source of danger.

Although the fire box shell is cylindrical in shape, it is ordinarily considered as having no pressure-resisting properties and is well stayed from the outer shell by staybolts which are screwed through both sheets and riveted over. The crown sheet forms the lower tube sheet and requires no special staying other than that provided by the tubes themselves. In accordance with the boiler codes, handholes are provided in the water leg near the bottom and at the line of the crown sheet for inspection and cleaning.

Ordinarily, feed water is admitted through a connection in the shell just below the lowest permissible water level. The internal feed pipe drops from this connection to a point well down in the water leg. This construction permits the feed water to be heated to the boiler temperature before coming in contact with the boiler water, which is effective in reducing internal strains. Any scale-forming material that can be precipitated by heat is thrown out where it can be readily removed through the blowoff connection located at the lowest point of the water leg.

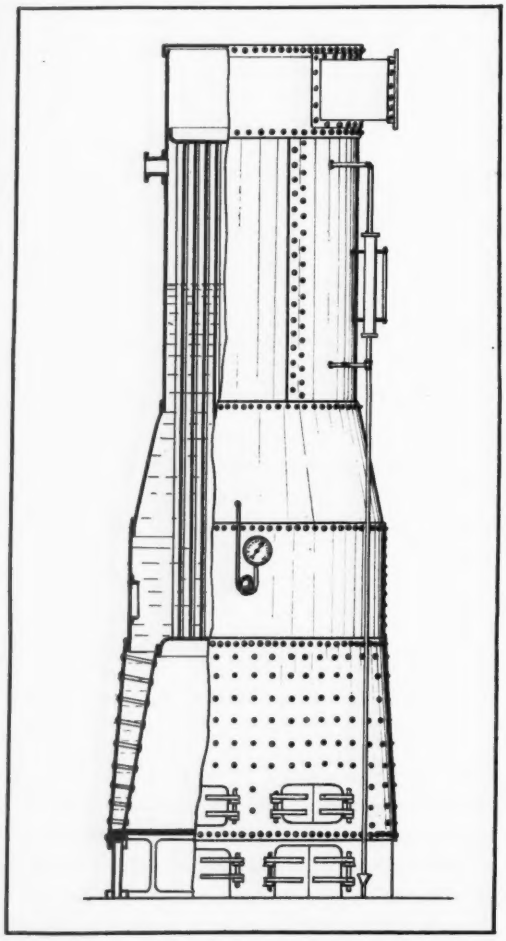


FIG. 5. THE SMITH BOILER HAS A LARGER WATER CAPACITY AND IS MORE ACCESSIBLE FOR CLEANING

Owing to the construction of the upper part of the boiler, the steam and safety valve nozzles are located in the shell as are also the water column connections. In order that the steam be as dry as possible when it reaches these nozzles, they are located as high as possible in the shell, immediately under the upper tube sheet in the case of exposed-tube boilers, and just below the top circumferential seam in submerged-tube boilers.

Manning and Smith Type Boilers

Where greater capacity is required than is obtainable with the ordinary vertical boiler, the Manning or Smith type is available. These boilers are built in sizes up to as much as 300 hp. They are of the exposed-tube type and, due to greater care in design, are comparable in efficiency with any of the other standard types of boilers. While some of the inherent disadvantages of the vertical boiler are present, many have been eliminated. The chief characteristic is the increased fire-box volume. In the Manning boiler, shown in Fig. 4, the lower part of the shell is larger in diameter than the upper portion, the two sections being connected by what is known as an ogee ring, having a double curvature, in section like the letter "s." This ring also takes up any strain imposed upon the boiler as a whole by reason of the unequal expansion of the tubes and the shell. Maintaining the same radial dimension on the water leg, this larger outer shell results in a larger diameter fire box which permits of burning more fuel with economy.

In the Smith boiler, shown in Fig. 5, the same result is obtained by using a conical sheet for the middle course in the shell. Inside the large lower section thus provided for, a conical fire box is placed. Besides the large fire box thus provided, this construction offers two additional advantages; it increases the water capacity of the boiler and it provides room for a man to work between the shell and the tubes, making thorough cleaning and inspection possible.

Boilers of this type in the larger capacities have comparatively long tubes which means a longer gas travel, greater heat absorption by the water in the boiler, consequently lower flue gas temperature and higher efficiency.

As a result of the International Conference on Customs Formalities at Geneva, Switzerland, an agreement is being signed by 34 nations designed to remove many of the most vexatious features of customs regulations. Many of these improvements were suggested by the International Chamber of Commerce and a number came from the American Section of the Chamber. As a result, harsh penalties for clerical and other trivial errors will be abolished; advertising matter will receive liberal customs treatment; consular office hours for handling trade documents will coincide with hours of business houses; invoices and certificates of origin will be standardized; travelers and their samples will be simply handled; inspection of travelers' baggage will be made on trains at European frontiers; a permanent body of customs experts will be established at Geneva to deal with international customs disputes; each nation will give full and prompt publication to its customs tariffs and regulations and to changes, such publications to be distributed through a central office at Geneva, the International Bureau of Customs Tariffs at Brussels, International Chamber of Commerce at Paris and the Inter-American High Commission at Washington.

A loyal and efficient organization is a living monument to any executive, and is the one essential factor for the accomplishment of big things.

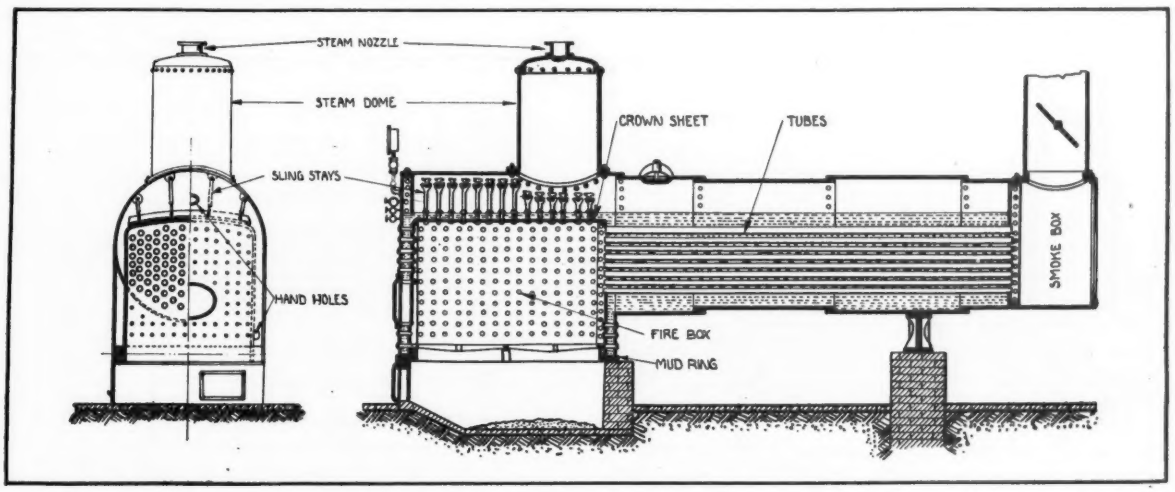
Locomotive Type Boilers

LOSSES DUE TO AIR LEAKAGE AND RADIATION REDUCED TO A MINIMUM IN LOCOMOTIVE TYPE BOILERS

IN ARRANGEMENT, the locomotive type boiler is essentially a horizontal tubular boiler with the furnace, surrounded by water legs, at one end and the smokebox at the other. The tubes through which the gaseous products of combustion pass from the furnace to the smokebox are rolled into the tube sheet at the furnace and into the head of the shell at the smokebox. They are 3 to 4 in. in diameter and placed in the shell below the water level.

Water surrounds the furnace on all four sides and the top, and in some cases a water bottom is provided below the ashpit, though this is usually omitted in stationary boilers. As the grate is rectangular in shape, necessitating the use of coal low in volatile combustible where smokeless combustion is essential. Efficiency, however, is fair, due largely to the absence of air leaks in the furnace walls and to the fact that the entire boiler can be insulated with covering to prevent radiation losses. The radiant heat of the furnace is not directed upon any portion of the boiler shell, so that bagged or blistered sheets are not encountered with this type of boiler.

Locomotive boilers have their greatest usefulness where a portable boiler is desired or where compactness is an essential feature. The water circulation within the boiler, however, is likely to be sluggish and because



LOCOMOTIVE TYPE BOILER IS CHARACTERIZED BY INTEGRAL, WATER-JACKETED FURNACE, HORIZONTAL SHELL AND FIRE TUBES BETWEEN FURNACE AND SMOKE BOX

the furnace construction necessitates the use of considerable flat surface under pressure and the crown sheet or roof of the furnace is under collapsing pressure, all of which requires special care in the use of stay bolts and braces. The bottoms of the water legs are closed, and being at the lowest part of the boiler, they form pockets where sediment may collect and be blown off.

In all cases, the use of stay bolts for bracing the flat surfaces of the water legs and of sling stays for supporting the crown sheet is in accordance with the A. S. M. E. Boiler Code as described elsewhere in this issue.

Access to the interior of a locomotive type boiler is gained through a manhole placed in the top of the shell near the center. Three handholes are usually provided through the front plate of the boiler for cleaning purposes, one over the crown sheet and one at the bottom of the water leg on each side of the furnace. As generally constructed, steam is taken from a steam dome which may be located over the center of the boiler or directly over the crown sheet. In some cases, however, a dry pipe is used in place of the steam dome.

Locomotive boilers are rapid steamers, yet have considerable water capacity which makes them suitable for handling fluctuating loads. They require comparatively small space, but the furnace is somewhat cramped, of the pockets formed by the water legs, which are difficult to clean, the boiler is subject to corrosion where inspection is difficult.

SPONGY METALS, such as cast iron, brasses and white metal alloys, lessen frictional resistance to a considerable degree, but the use of unguents is necessary for good results. Lubricants may be solid, such as graphite, semi-solid as greases, or liquid as oils. The following are the customary lubricants for the purposes indicated:

Low temperatures: light mineral lubricating oils.
Intense pressures: graphite or soapstone.
Heavy pressures at low speeds: graphite, tallow.
Heavy pressures at high speeds: sperm, castor, heavy mineral oil.
Light pressures at high speeds: sperm, olive, rape, refined petroleum.
Ordinary machinery: lard-oil, tallow-oil, heavy mineral oil.
Steam cylinders: mineral or compounded mineral oils.
Steam turbines: heavy paraffine base mineral oil.
Delicate mechanisms: clarified sperm, porpoise, olive, light mineral.

Scotch Marine Boilers

General Consideration of Types. Details of Construction

SCOTCH BOILERS may be classified according to two different types, i. e., the wet-back type, which is the true form of Scotch boiler used in marine practice, and the dry-back type, which is a modification of the marine type for stationary service. In either case the general arrangement of the component parts is the same, and the dry-back boiler differs from the wet-back only in the fact that in the former, the back connection or combustion chamber is made external to the boiler shell proper, instead of being made an inseparable part of it, as is the case in the wet-back type. In the dry-back type, too, the back of the combustion chamber is usually lined with fire brick. In the wet-back boiler, no brick work of any kind is employed as furnace and combustion spaces are entirely surrounded by water.

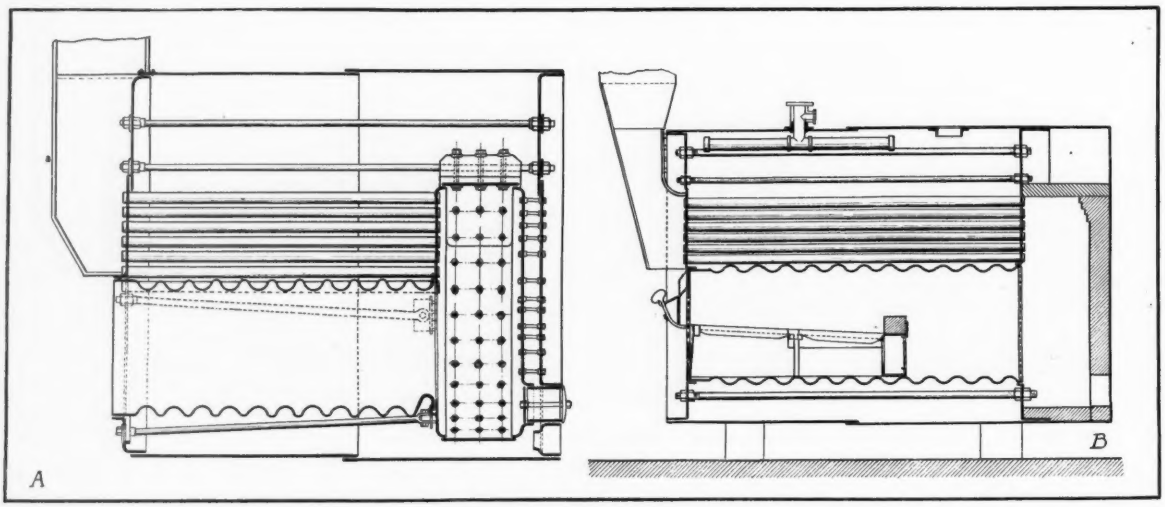


FIG. 1. TWO TYPES OF SCOTCH BOILERS. A, THE WET BACK OR THE TRUE SCOTCH BOILER. B, THE DRY BACK OR STATIONARY TYPE

Figure 1-A shows the arrangement of parts in a typical Scotch boiler. It consists essentially of a cylindrical drum into which are fitted one or more cylindrical furnaces opening into combustion chambers at the rear.

Immediately above the furnaces are fitted a number of tubes or flues which extend from the combustion chambers to the front head of the boiler, so as to discharge the gases into the uptake connection.

As the heads of this boiler are flat and of considerable area, they require strong bracing. To secure strength, therefore, the boiler is braced with a number of stay rods, which run through the boiler from the front to the back head, being held in place by nuts on each end. In addition to these stay rods, as they are called, some of the tubes, known as stay tubes, are made extra heavy and are threaded and screwed into the heads in order that they too may act as braces.

Combustion chambers are located at the rear end of the boiler and are secured to the rear head by short stay bolts. They are also secured to each other and to the shell by the same method, while the front of the chamber is secured to the front tube sheet of the boiler by the stay tubes and rods referred to in the preceding paragraph. The crown sheet which is the top of the combustion chamber is securely braced by four steel girders. Bolts running through the crown sheet pass in between the plates of these girders and are held in place by nuts. Where an internally fired boiler for relatively large power is desired, the Scotch boiler gives good satisfaction. It is self contained, requires no brick setting, and needs little overhead room. There is minimum of radiation loss and little chance for leakage of air into the furnace. The circulation, however, is not always positive, and the water below the furnace may be considerably below the average temperature, giving rise to expansion stresses. This is one of its chief disadvantages and to overcome it certain manufacturers have introduced modifications, some of which are quite successful.

Scotch boilers will burn either bituminous or anthracite coal, and may also be adapted to the use of oil. By building the Dutch oven extension furnace, they may be used to burn wood refuse to good advantage.

Furnaces

Furnaces for Scotch boilers are usually of the corrugated type, but if desired may also be had in either the Adamson expansion joint or in the Bolling ring type of construction, all of which are illustrated in Fig. 2. The Bolling ring type has the approval of the British board of trade and is extensively used in England.

In the case of the corrugated type, which is most common in this country, the furnace is made of one sheet of low carbon steel about ½ in. in thickness, having a tensile strength of about 60,000 lb. These sheets are cut to size, rolled to a cylinder and the joints lapped and welded. They are then corrugated by means of a specially shaped mandrel which is put inside the

furnace while it is hot-rolled. The reason for corrugating the furnace is to increase the strength, to allow for expansion and contraction and to increase the heating surface.

Where two or more furnaces are fitted in a boiler, it is customary to alternate the corrugations of adjoining furnaces. In order that it may be possible to remove the furnace if necessary, the straight part at the back end has a smaller diameter than the corrugations and the straight part at the front end has a larger diameter than the corrugations, so that the furnace can enter the furnace hole in the lower sheet of the boiler. In some cases furnaces are made non-removable.

Grate bars are supported just below the horizontal diameter of the furnace. Where the bars are in two lengths, one end of the front bar rests on the dead plate and the other end on a bearer bar. The rear bar also has one end on the same bearer bar, while the other end rests on the bridge wall. The latter is located at

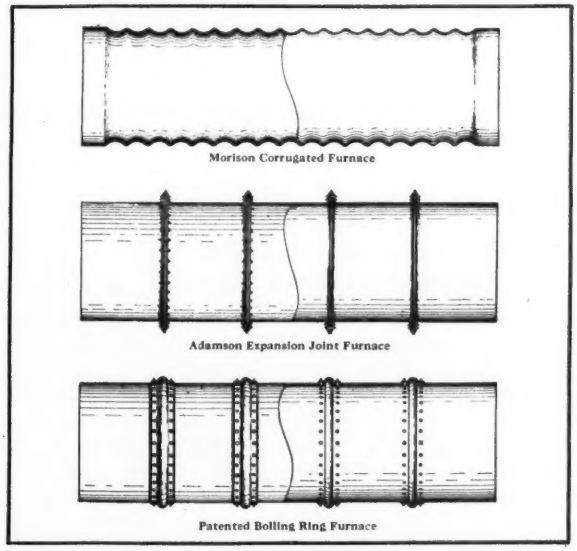


FIG. 2. THREE TYPES OF FURNACE CONSTRUCTION FOR SCOTCH BOILERS

the rear of the furnace where it connects into the combustion chamber. In the dry-back Scotch boiler, the bridge wall is usually located some distance forward of the combustion chamber opening, as the dry-back type is longer than the wet-back type.

In the wet-back type of boiler, the Wager patented type of bridge wall has proved highly satisfactory. This consists of a cast-iron member running across the rear of the furnace and serving as a support for a number of cast-iron sections, which, when all are properly assembled, form the bridge wall. All these sections are interchangeable except the two adjacent to the sides of the furnace, which are curved so as to conform to the shape of the corrugations and are held in place in the same manner as the center sections. Details of this construction are shown in Fig. 3.

Two methods are in use for securing the furnace to the front head and the combustion chamber. If the furnace has a flanged collar, the front sheets of the boiler and combustion chamber are straight and rivets pass through the collar and the sheets. If the furnace

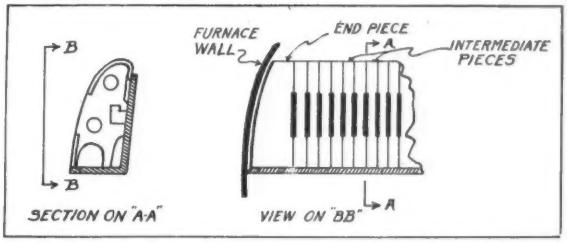


FIG. 3. THE WAGER PATENTED BRIDGE WALL FOR SCOTCH BOILER FURNACES

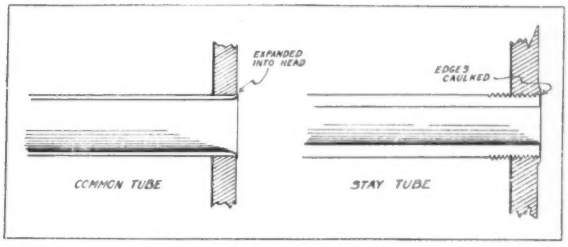


FIG. 4. DETAILS OF TUBES FOR SCOTCH MARINE BOILERS

ends are straight, the combustion chamber front sheet and the front head sheet are flanged, the furnace in this case being riveted to the inside of the flange.

Tubes

Two kinds of tubes are used in the Scotch boiler, common tubes and stay tubes. Common tubes are expanded into both front and rear tube sheets, and are beaded over, sometimes only in the rear tube sheet and sometimes in both front and rear sheets, the beading serving to protect the ends of the tubes from the action of the hot gases. As was the case with the furnace flues, the tubes are generally made a trifle larger at the front end than at the rear to facilitate removal. This method of expanding the tubes into the tube sheets forms a

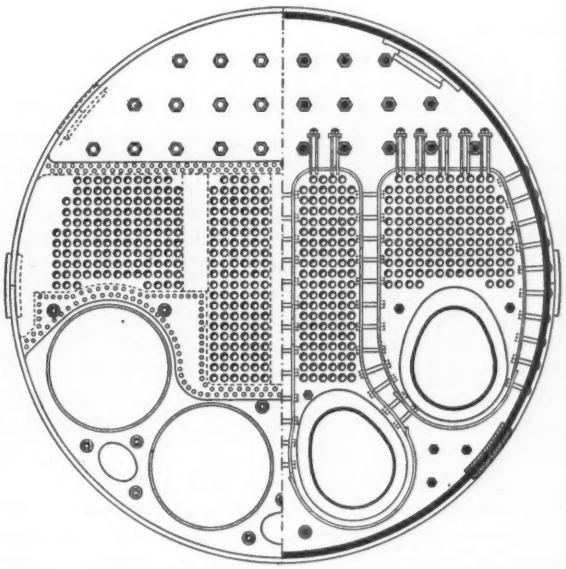


FIG. 5. FRONT HEAD (LEFT) AND COMBUSTION CHAMBER (RIGHT) OF A SCOTCH MARINE BOILER, SHOWING ARRANGEMENT OF TUBES AND COMBUSTION CHAMBERS

good steam-tight joint but does not stay the head in any way. For this reason, that is to contribute strength, stay tubes are put in.

Common tubes are made of a good quality of charcoal iron, about 1/16 in. thick, are lap welded and have an internal diameter of 2¼ in. Stay tubes are made considerably heavier and are specially fitted to the tube sheets by screw joints so that they can act as stays between the tube sheets. In tapping the holes in the tube sheets, a long tap is used so that it may pass through both the front head and the rear head at one time, in order that a continuous thread may be cut. Of the total number of tubes in the boiler, from 20 to 30 per cent are stay tubes, depending upon the thickness of the tube sheet.

Holes in the tube sheets are always drilled in vertical and horizontal rows with the greater spacing between the vertical rows. Such an arrangement gives the best chance to clean the tubes on the water side, and it is also supposed to give better circulation. A typical arrangement of the holes in the front head of a Scotch boiler is shown in Fig. 5. This diagram also shows the method of securing the combustion chamber.

In any boiler, there must be provided a space where the partly burned volatile gases driven from the coal can combine properly with the oxygen brought in with the air through the fuel bed. In the Scotch boiler, this space is provided in the form of combustion chambers at the rear end of the boiler.

These combustion chambers are built up of steel plates, secured together by single-riveted lap-welded joints. The front of the combustion chamber serves as the rear tube sheet, hence as a large number of holes are cut in this sheet for the tubes, this sheet is made of heavier material than other parts of the chamber. The front and rear sheets are flanged in, the sides, the bottom and the crown sheets being riveted to these flanges.

When assembled in the boiler, the combustion chambers are secured together by means of staybolts, as shown in Fig. 5. The present tendency is toward providing a separate combustion chamber for each furnace, although in many cases one chamber will serve two or more furnaces. Thus, a four-furnace boiler may have two combustion chambers or there may be three chambers, the two inside furnaces being served by one chamber and each of the outside chambers having a chamber. In other cases, four separate chambers would be used.

In the dry-back Scotch boiler a single combustion chamber is usually provided for all furnaces and is lined with fire brick, which becomes red hot when the boiler is in use, thus aiding combustion.

Strength of Boiler Parts

No Boiler Is Stronger than Its Weakest Part Hence the Seemingly Most Unimportant Part Must Be Designed with Exacting Care

"Have you heard of the wonderful one-hoss shay,
That was built in such a logical way
It ran for a hundred years to a day,
And then, of a suddent, it—ah, but stay,"
. . . —Holmes

BOILERS ARE not built after the fashion of the justly renowned one-hoss shay for the reason that in the first place it would be impossible, and in the second, even were it possible, such construction would be undesirable.

"There is always somewhere a weakest spot—." In boilers this spot is usually, though not always, in the shell, which, if built in accordance with an accepted code, has a factor of safety of not less than five; other parts such as tubes, headers, etc., having a somewhat greater margin on the ultimate strength.

The maximum allowable working pressure on the shell or drum of a boiler is determined by the strength of the weakest course, figured from the thickness of the plate, t; the tensile strength, T.S., of the material; the efficiency, E, of the longitudinal joint, or of the ligament between the tube holes, whichever is least; the inside diameter of the course 2R; and the factor of safety, F.S., which is taken as 5 for new boilers. Expressed mathematically, maximum allowable working pressure in pounds per square inch is

$$p = (T.S. \times t \times E) \div (R \times F.S.)$$

Ordinarily boiler steels whether of the flange or firebox variety have a specified ultimate tensile strength of from 55,000 to 65,000 lb. per sq. in. Steels of lower tensile strength may, however, be used, if it is thought expedient, and the strength of the boiler computed on that basis.

Aside from the question of strength, materials used in boiler construction should possess certain other qualities, if they are to be suitable for the purpose. The high pressures and temperatures encountered call for a material the chief property of which should be ductility. While strength is a desirable attribute, varying conditions of expansion and contraction, of shock and excess pressure, and of corrosion, erosion and overheating call for a tough material which will survive rough usage and give adequate warning before rupture occurs.

In accordance with these demands the A. S. M. E. boiler code specifies the following qualities:

	Flange	Firebox
Carbon		Plates ¾in. thick and under. 0.12–0.25 per cent. Plates over ¾in. thick. 0.12–0.30 per cent.
Manganese	0.30–0.60 per cent	0.30–0.50 per cent.
Phosphorus, Acid	Not over 0.05 per cent.	Not over 0.04 per cent.
Phosphorus, Basic	Not over 0.04 per cent.	Not over 0.035 per cent.
Sulphur	Not over 0.05 per cent.	Not over 0.04 per cent
Tensile strength, lb. per sq. in.	55,000–65,000	55,000–65,000
Yield point, min. lb. per sq. in.	0.5 tens. str.	0.5 tens. str.
Elongation in 8-in., min., per cent	1,500,000 ÷ tens. str	1,500,000 ÷ tens. str.

In addition to this it is specified that a bend-test specimen must bend cold through 180 deg. without cracking on the outside of the bend: For material 1 in. or less thick, around a pin whose diameter is equal to the thickness; and for material thicker than this, around

a pin whose diameter is twice the thickness of the specimen.

To meet the code requirements the plate must not be thinner than 0.01 in. under the gage specified.

It is usual to assume that the stresses in a given course of a boiler drum or shell are uniform, though strictly, such is not the case. Stresses in the flange of a head are extremely severe, but they do not permit of ready analysis. While they occur at a point having considerable inherent strength due to the circumferential joint and flange of the head, grooving and local bending stresses often cause rupture at this point. The stress diagram shown in Fig. 1 represents the results of some experimental determinations made some years ago and presented before the Engineering Association of New South Wales. Stresses shown in the spherical segment of the head are conjectural. The variations of stress in the vicinity of the lap joints accord with the usual inferences on this point. The stresses in the head flanges indicate a bending action with great tension on the innermost fibres and compression on the outside fibres.

Strength of Riveted Joints

Were it feasible from a manufacturing point of view, the most efficient use of the metal employed in the construction of the boiler shell or drum could be obtained, if there were no joints, in which case the efficiency of

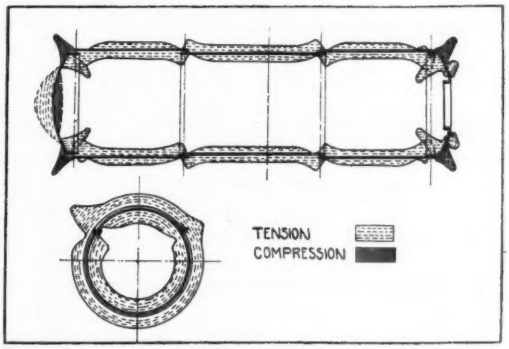


FIG. 1. VARIATIONS IN STRESS OF A BOILER DRUM UNDER PRESSURE

the fabrication would be 100 per cent. Such construction is of course impractical as joints, both circumferential and longitudinal, must be used. Under these conditions the designer must make the most efficient joint possible, commensurate with cost.

Two general classes of riveted joints are used in boiler shell construction, the longitudinal anl the circumferential. The stresses, normal to the seam, involved in these two joints are quite different, consequently different types of construction are used. Owing to the physical properties of the cylindrical shape employed for boiler shells, the force tending to cause rupture along a circumferential line is only half that along a line parallel to the axis as is evident from an examination of the two equations for resistance to rupture. For the girth seam, the force tending to rupture the plate is $0.7854\ D^2p$ and the resisting force, $3.14\ Dt \times T.S.$, where D is the diameter of the shell; p, the bursting pressure; t, the thickness, and T.S., the ultimate tensile strength of the plate, all dimensions in inches.

At the point where rupture is impending these two forces are in equilibrium, hence,

$$0.7854\ D^2p = 3.14\ Dt \times T.S.$$

Solving for pressure,

$$p = 3.14\ D \times t \times T.S. \div 0.7854\ D^2$$
$$= 4t \times T.S. \div D$$

In the longitudinal joint the acting force is Dlp and the resisting force $2tl \times T.S.$ Under the conditions of equilibrium,

$$Dlp = 2tl \times T.S.$$

Solving for pressure,

$$p = 2tl \times T.S. \div Dl$$
$$= 2t \times T.S. \div D$$

From these two equations, it is apparent that the longitudinal element has twice the resistance to rupture of the circumferential. It follows then that to provide for a certain safe working pressure the efficiency of the circumferential joint need be only half that of the longitudinal joint. For this reason, it is customary to use only the simplest kind of joint on the former, single riveted or sometimes double riveted lap joint, and the more complex and more efficient butt joints on the latter.

Lap joints may be either single or double riveted depending on the efficiency desired. Normally single riveted lap joints have a range of efficiencies from about

Thickness of Plate inches	Thickness of Straps inches	Diameter of Rivet. RivetHole inches	Efficiency Per Cent	Pitch inches	C inches	E inches
1/4	1/4	11/16	82.8	2	1 1/16	2 1/8
5/16	9/32	13/16	81.9	2 1/4	1 1/4	2 7/16
3/8	5/16	13/16	81.9	2 1/4	1 1/4	2 7/16
7/16	3/8	15/16	81.3	2 1/2	1 7/16	2 3/4
1/2	7/16	15/16	81.3	2 1/2	1 7/16	2 3/4

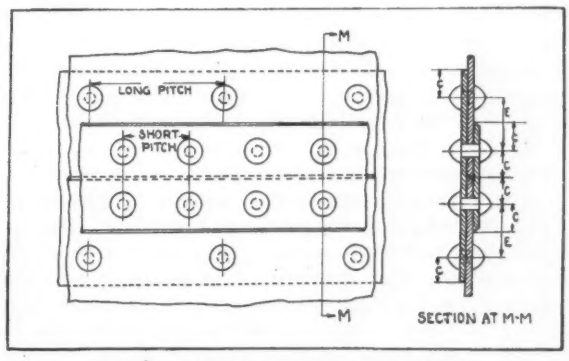


FIG. 2. DOUBLE RIVETED BUTT JOINT

56 to 60 per cent, decreasing as the thickness of the plate increases from 1/4 to 1/2 in. Double riveting is employed where greater efficiency is desired; the efficiency of this construction is almost constant at a value of about 68 or 69 per cent, decreasing slightly as the plate thickness increases. On the single riveted joint the pitch increases with the plate thickness from about 1 3/4 in. for 1/4-in. plate to 2 1/2 in. for 1/2-in. plate. On the double riveted joint the pitches increase from 2 1/4 to 3 3/8 in. for the same variation in plate thickness. When lap joints are properly proportioned and well constructed, failure will almost invariably occur by tearing of the plate between rivet holes; i.e., the efficiency in tension is the determining factor.

Butt joints are made up in a variety of forms such as the double, triple and quadruple riveted, as shown in Figs. 2, 3, and 4. The efficiency of the joint is least with the double riveting and greatest with the quadruple, but, largely because of the increased cost of construction, all butt joints are not made quadruple riveted. For boilers designed for moderate pressures it is more economical to use a greater thickness of plate than to resort to the more complex fabrication.

Thickness of Plate inches	Thickness of Straps inches	Diameter of Rivet Hole inches	Efficiency Per Cent	Pitch inches	C inches	D inches	E inches
1/4	1/4	11/16	87.5	2 3/4	1 1/16	1 3/4	2 1/8
3/8	5/16	13/16	88.4	3 1/2	1 1/4	1 7/8	2 7/16
1/2	7/16	15/16	88.3	4	1 7/16	2	2 3/4
5/8	1/2	1 1/16	86.7	4	1 5/8	2 1/4	3
3/4	1/2	1 3/16	85.5	4 1/8	1 5/16	2 3/8	3 1/4
7/8	5/8	1 5/16	84.1	4 3/8	2	2 5/8	3 1/2
1	3/4	1 7/16	83.4	4 3/4	2 3/16	2 7/8	3 3/4

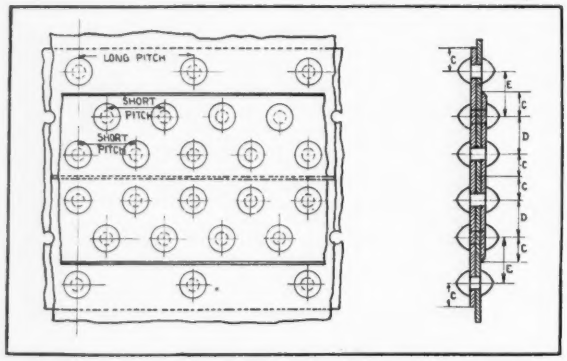


FIG. 3. TRIPLE RIVETED BUTT JOINT

Generally, double riveted construction is used only for plate thicknesses less than 1/2 in. For plates from 1/4 to 1/2 in. thick the efficiency varies from about 83 to 80 per cent. Failure will occur due to tearing of the plate between rivets in the outer row.

Where greater efficiency is desired, triple-riveted joints are used for plate thicknesses up to 1 in. In properly designed joints, failure is most likely to occur by tearing of the plate between rivets in the second row and shearing of a rivet in the outer row, for plates from 7/8 to 1 in. thick. Joints on the thinner plates fail by tearing of the plate between rivets in the outer row. The minimum efficiency varies from about 87 per cent for 1/4-in. plates to 83 per cent for 1-in. plates.

Quadruple riveted joints are usually used on plates over 1 in. thick and may be used on thinner ones. Efficiencies vary from about 93 per cent for the 1/4-in. plate to 86 per cent for the 1 1/4-in. plate. For plate thicknesses from 7/8 to 1 1/4 in. failure will occur by tearing of the plate between rivets in the third row and shearing of the rivets in the two outer rows. On the thinner plates, failure is by tearing of the plate between rivets in the outer row.

For plates exposed to the direct heat of the fires, as is the case in horizontal return-tubular boilers, plate thickness exceeding 1 in. is not permitted owing to the danger of overheating. This applies also to the total thickness of plate at the circumferential joint. When shell plates exceed 9/16 in. in thickness they must be planed down to 1/2 in. at the joint.

Welded Joints

Although the art of welding has reached a high degree of perfection of late years, this method of joining plates is not generally looked on with favor for parts subjected to pressure. This is due to the fact that whereas the final strength of a riveted joint may be foretold quite accurately from a consideration of the design of the joint, the ultimate strength of a welded joint, while it may be as great as that of the plate, can be determined with certainty only by an actual test to destruction. The efficiency of such a joint depends entirely upon the skill of the man who made it.

The American Society of Mechanical Engineers boiler code specifies that the ultimate strength of a joint which has been properly made by the forging process, shall be taken as 35,000 lb. per sq. in. with steel plates having a range in tensile strength of from 45,000 to 55,000 lb. per sq. in. Autogenous welding may be used in boilers in cases where the strain is carried by other construction which conforms to the requirements of the code and where the safety of the structure is not dependent upon the strength of the weld.

Where heads in boiler drums are not designed to act as tube sheets, as they are in horizontal return-tubular boilers and some forms of water-tube boilers, they are invariably dished or bumped as this form of construc-

Thickness of Plate inches	Thickness of Straps inches	Diam. of Rivet Hole inches	Efficiency Per Cent	Pitch inches	C inches	D inches	E inches	F inches
1/4	1/4	11/16	93.8	2 3/4	1 1/16	1 3/4	2 1/8	2 1/4
3/8	5/16	13/16	94.2	3 1/2	1 1/4	1 7/8	2 7/16	2 3/4
1/2	7/16	15/16	94.1	4	1 7/16	2	2 3/4	3 1/8
5/8	1/2	1 1/16	93.4	4	1 5/8	2 1/4	3	3 5/16
3/4	1/2	1 3/16	92.7	4 1/8	1 5/16	2 3/8	3 1/4	3 5/16
7/8	5/8	1 5/16	91.2	4 3/8	2	2 5/8	3 1/2	3 7/8
1	3/4	1 7/16	90.2	4 3/4	2 3/16	2 7/8	3 3/4	4 1/4
1 1/8	3/4	1 7/16	88.0	4 3/4	2 3/16	2 7/8	3 3/4	4 1/4
1 1/4	7/8	1 7/16	86.8	5	2 3/16	2 7/8	3 3/4	4 5/16

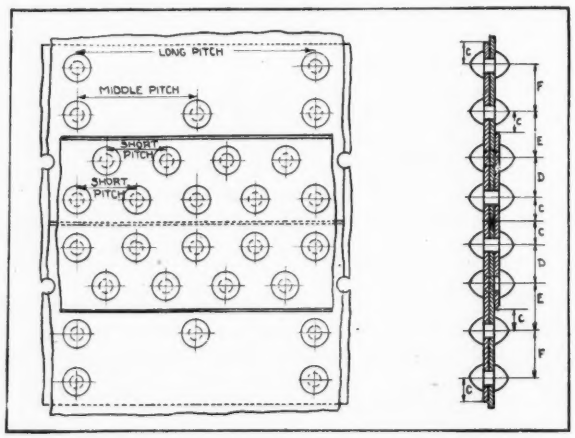


FIG. 4. QUADRUPLE RIVETED BUTT JOINT

tion is inherently stable under pressure and requires no staying.

Heads and Stays in Boiler Shells

Bumped heads are of two varieties: those which are concave to the pressure, sometimes called plus heads, and those convex to the pressure or minus heads. Of the two, the former is inherently the stronger. Ordinarily the radius of curvature is made equal to the diameter of the shell that goes with it. For heads concave to the pressure and having no manholes, the allowable working pressure may be found from the equation

$$p = 2\,T.S.\,(t - \tfrac{1}{8}) \div 5.5\,L$$

or the thickness required for a given pressure may be found by transposition

$$t = (5.5\,Lp \div 2\,T.S.) + \tfrac{1}{8}$$

where t is the thickness of the head in inches; p, the maximum allowable working pressure in pounds per square inch gage; T.S., the ultimate tensile strength of the material, and L, the radius of curvature of the head.

Where a manhole is cut into the head the allowable working pressure may be determined from the relation

$$p = 2\,T.S.\,(t - \tfrac{1}{4}) \div 5.5\,L$$

For heads convex to the pressure, the maximum allowable working pressure is taken as 60 per cent of that allowed on plus heads of the same dimensions.

Where the radius of curvature is less than 80 per cent of the diameter of the drum to which the head is attached, the plate thickness should be at least that found by making L equal to 80 per cent of the drum diameter.

Code specifications require that when dished heads are of less thickness than that called for by the foregoing relations they shall be stayed as flat surfaces, no allowance being made for the holding power due to the spherical form. The code also requires that the corner radius of an unstayed head, measured on the concave side, shall be not less than 1½ in. nor more than 4 in. and within these limits shall not be less than 3 per cent of the radius of curvature of the main section of the head.

The strength of flat heads requiring staying is almost entirely independent of the thickness of the head. This dimension enters into the calculations only in determining the width of the annular ring adjacent to the flange, which is considered to be supported by the flange itself and does not require additional staying. The thickness is determined by factors other than strength.

In horizontal return-tubular boilers, the rolling of the tubes into the tube sheet is sufficient to support that portion of the sheet adjacent to the tubes. The additional area requiring support may be found from the equation

$$A = \frac{4 \times (H - d - 2)^2}{3} \sqrt{\frac{2(R - d)}{(H - d - 2)}} - 0.608$$

where d is the unstayed distance from the shell in inches which may be determined from the relation

$$d = 5\,T \div \sqrt{p}$$

In these equations A is the area to be stayed; H, the distance from the tubes to the shell; R, the radius of the shell; T, the thickness of the head in sixteenths of an inch, and p, the maximum allowable working pressure. In the expression (H — d — 2), 2 is the distance in inches from the tubes that requires no staying.

Where stays are required in horizontal return-tubular boilers, either through-stays or diagonal crow-foot or gusset stays may be used. To support the area under the tubes, through-stays are always used; diagonal stays are not permissible for the reason that they would have to be riveted to the shell at a point exposed to the direct heat of the furnace. This construction would mean a double thickness of metal at this point which is, of course, not allowable owing to the liability to overheating of the metal.

Through-stays are usually upset at the ends so that the net cross-sectional area at the root of the threads is equal to that of the body of the stay. Such stays may be threaded at both ends or threaded at one end and provided with an eye at the other which fits over a pin fixed to the head. The threaded end is screwed into the head and locked there by means of a nut on either side of the sheet as shown in Fig. 5. A washer is required on the outside end, the diameter of which should be not less than 2½ times the diameter of the stay.

For unwelded through-stays having a diameter not exceeding 1½ in. and where the length does not exceed 120 diameters, the allowable stress is 9500 lb. per sq. in. For greater lengths, the allowable stress should be reduced to 8500 lb. For diameters over 1½ in. and for lengths not greater than 120 diameters, the stress may

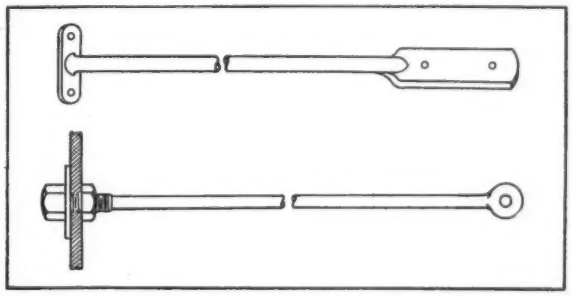


FIG. 5. TYPES OF STAYS COMMONLY USED IN BOILER SHELLS

be taken as 10,400 lb. but for greater lengths, only 9000 lb. per sq. in.

Diagonal stays, such as shown in Fig. 5, must be larger than through-stays supporting the same area under the same pressure by an amount equal to one divided by the cosine of the angle between the stay and the shell.

The cross-sectional area through the braces of diagonal stays where they are attached to the shell should be at least equal to the required total rivet section which should be 1¼ times the net area of the brace.

Boiler Tubes

Boiler tubes are specified in accordance with their outside diameter, expressed in inches, and the thickness of tube wall. The advantage in specifying the outside diameter is that the shop fit at the tube ends is always determined by that dimension. The thickness of tube wall is specified in accordance with the Birmingham wire gage which has been universally adopted as standard by boiler tube manufacturers. For a given size of boiler tube the outside diameter will always be the same, regardless of the thickness of the wall, and, if it is de-

sired to make that size with a heavier wall, the additional metal must be added to the inside of the tube.

Standard specifications of the A. S. M. E. boiler code committee for the workmanship on boiler tubes provides that finished tubes 3½ in. or under in outside diameter shall be circular within 0.02 in. and the mean outside diameter shall not vary more than 0.015 in. from the size ordered. For tubes over 3½ in. in outside diameter, these variations shall not exceed 0.5 per cent of the outside diameter. All tubes shall be carefully gaged to B.W.G. and shall be not less than the gage specified. Tubes on which the standard slot gage will go on tightly at the thinnest point, will be accepted. The length shall be not less, but may be 0.125 in. more than that ordered.

Minimum thickness of tubes for fire-tube boilers, where the maximum allowable working pressure does not exceed 175 lb. per sq. in., should be as follows:

Diameters

1 in. or over, but less than 2½ in.....No. 13 B.W.G.
2½ in. or over, but less than 3¼ in.....No. 12 B.W.G.
3¼ in. or over, but less than 4 in.....No. 11 B.W.G.
4 in. or over, but less than 5 in.....No. 10 B.W.G.
5 in.....No. 9 B.W.G

For each increase of one gage in thickness above that shown in the table, the maximum allowable working pressure will be increased by 200 lb. divided by the diameter of the tube in inches.

The maximum allowable working pressure for tubes for fire-tube boilers is given by the equation

$$p = [(t - 0.039)\ 18{,}000 \div D] - 250$$

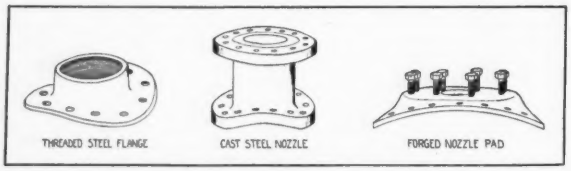


FIG. 6. NOZZLES AND NOZZLE FITTINGS COMMONLY USED ON BOILER DRUMS OR SHELLS

Where p is the maximum allowable working pressure in pounds per square inch gage; t, the thickness of the tube wall in inches, and D, the outside diameter of the tube in inches.

For any desired pressure and tube diameter the thickness required in inches may be found by transposition to be,

$$t = [(p + 250)\ D \div 18{,}000] + 0.039 \text{ in.}$$

Steam Nozzles

Whenever openings such as are required for the delivery of steam are cut in boiler shells, it is necessary to provide reinforcement to the shell at that point and at the same time provide a practical method for making the steam pipe connection in the field. Standard practice requires that all openings 2 in. diameter or larger in the shells of return-tubular boilers shall be properly reinforced with a suitable steel reinforcing flange riveted on. The fitting known as the steam nozzle meets all of the above requirements. The lower or saddle flange forms a reinforcing ring for the opening in the shell and the opposite flange serves as half of the coupling for the steam pipe connection.

Main steam outlets on boilers which are to carry 100 lb. pressure may be reinforced with a heavy pressed steel screwed flange securely riveted to the shell. On pressures above this a flanged nozzle is to be preferred on all outlets over 3 in. diameter. In some cases a reinforcement known as a nozzle pad is used. It is similar to the threaded flange except that it is arranged for a bolted joint with the fitting which matches up to it. Standard types of nozzles and fittings are shown in Fig. 6. When dry pipes are used it is customary to thread the bore of the nozzle so that a nipple may be used as a connection to the dry pipe. Another method of connecting the dry pipe to the steam nozzle is by means of a plain nipple which forms a slip fit. The dry pipe is then held in place by anchorage to the shell. The A. S. M. E. boiler code specifies flanged connections for safety valves over 3 in. in size and it is customary to have a nozzle riveted to the boiler shell where this condition must be satisfied.

Boiler manufacturers' practice varies greatly in the matter of steam nozzle location. In many cases the steam nozzle will be found at about midway the length of the shell, in which case the safety valve nozzle may be found either forward or to the rear of the steam nozzle. The size of the safety valve will determine the size of nozzle to be used for its connection to the boiler. The size of steam discharge nozzles is primarily determined by standard specifications for return-tubular boilers. Steam velocities through the discharge nozzles of different sized boilers will vary from 6500 to 10,500 ft. per min. under operating conditions of rated capacity.

Standard specifications for boilers provide that cast iron shall not be used for nozzles or flanges attached directly to the boiler. This is another way of stating that boiler nozzles must be made of either forged or cast steel. When the latter material is used, it must have been carefully annealed in order to re-fuse the grain of the metal and to release locked up stresses which are set up within the casting during the cooling period after pouring in the foundry.

Manholes Must Be Reinforced

To afford access for a man inside of a boiler, to meet the needs of the manufacturer and to provide for adequate interior cleaning and inspection, certain manholes are required in shells and drums. These openings are universally elliptical in shape and are just large enough to allow a man to get through. The A. S. M. E. code specifies that they shall not be smaller than 11 by 15 in. or 10 by 16 in.

To compensate for the holding power of the metal that has been cut away in making a manhole opening every such opening must be adequately reinforced. For this purpose, flanged frames or saddles are commonly employed. They are riveted to the shell with a single row of rivets on shells under 48 in. in diameter and with a double row for larger sized shells. In head plates modern practice permits of simply flanging over the edges of the hole. This flange should be at least three times the thickness of the plate deep, measured from the outside surface. Since the plate is stiffened by the flange, the hole does not materially weaken the head. Where manholes are cut in the shell the minor axis of the ellipse should be parallel to the longitudinal axil of the shell.

Furnace Construction

PROPORTIONS, SPECIAL BAFFLING, ARCHES AND LININGS, COVERED IN ARTICLES WHICH FOLLOW, ARE IMPORTANT FACTORS IN FURNACE DESIGN

ECONOMY of boiler operation can be no better than the combined efficiency of boiler, grate and furnace. A boiler of approved design and a grate or stoker suitable for burning a given coal will not necessarily prove satisfactory in combination unless furnace proportions are given careful consideration. There is no method by which furnace efficiency can be separated from that of the boiler and grate, therefore a study of furnace proportions must be based largely upon results obtained in actual installations.

In general, furnace proportions are based upon the physical state and composition of the coal to be burned, the rate of firing and the type of stoker or method of firing. Combustion of anthracite coal is practically completed within the fuel bed, therefore large furnace volumes or mixing arches are not necessary. With coals high in moisture and volatile matter it becomes imperative to build furnaces of large dimensions to get the best economy.

For hand-fired return tubular boilers under which western coals are to be used, such settings as the Chicago or double arch type have proved satisfactory. They depend more upon breaking up the gas lanes and exposing the gas to the radiant heat from brickwork than upon large furnace volumes.

For the above combination, practice allows about 28 in. from the grate to shell for 42-in. diameter boilers and 38 in. for 84-in. diameter boilers. It is good practice to increase these dimensions wherever practicable. For stoker-fired installations where high ratings are expected, the problem becomes more complex. Here the length of gas travel becomes important because it bears directly upon furnace construction, maintenance and efficiency.

Wide and comparatively low furnaces are probably more economical to maintain than high and narrow ones, due to the lower side wall temperatures resulting from proximity of the boiler tubes. In the narrow setting, this cooling effect will be less pronounced and accordingly the brickwork must withstand higher temperatures.

LENGTH OF GAS TRAVEL IS IMPORTANT

Investigations by the Bureau of Mines have led to the conclusion that length of gas travel is an important factor in the completeness of combustion. It would seem that a long, narrow combustion space is more efficient than a short wide one having the same cubic contents. In the long, narrow space, the gas travels at a higher velocity and is, therefore, better mixed so that combustion is hastened. The gas remains the same length of time in the short, wide furnace but the velocity is lower.

In these tests, the gas tended to flow in stratified streams through the long horizontal combustion space, in spite of the whirling action which was evident above the Murphy stoker and which would seem to cause the gas to form a uniform mixture a short distance beyond the fuel bed.

FURNACE VOLUMES HAVE BEEN GREATLY INCREASED

Recent investigations by Edwin B. Ricketts published in Mechanical Engineering and shown in the table, indicate the tendency in proportioning furnaces for stoker-fired installations. In the older plants, it was not uncommon to find furnace volumes of 1 cu. ft. per rated horsepower. This may be contrasted with the recent chain-grate installation at Waukegan which provides 5.75 cu. ft. per rated horsepower and the Delaware station underfeed-stoker installation which is proportioned for 4.80 cu. ft. per rated horsepower.

Combustion is more difficult to control on the chain-grate stoker than on the underfeed type. Green coal is fed and burned progressively so that large volumes of gas are driven off at the front end of the grate, where

by recessing the side walls and leaving an expansion space at either end of the bridge wall.

there is usually a deficiency of air. In the middle grate zone, more complete combustion will take place, while at the back end there is likely to be a great excess of air. This condition produces a stratification of gas which must be properly mixed, if complete combustion is to take place before the gas is cooled by contact with the boiler heating surface.

With the underfeed type of stoker, methods of arch and steam jet mixing may be used on existing low-set installations, but a larger combustion space will over-

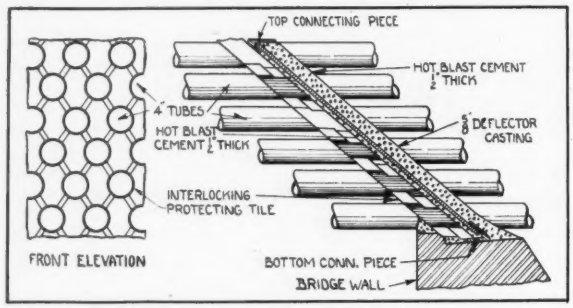


FIG. 1. CAST-IRON FLAME PLATES, TILE AND HIGH TEMPERATURE CEMENT BAFFLE

come the necessity for such methods. In chain-grate installations, an ignition arch in front and sometimes a reverse arch over the rear end of the stoker are used.

Longitudinal and cross-drum boilers are now set with the front header 10 to 15 ft. above the floor line. Stirling type boilers are often set with the mud drum 8 to 15 ft. above the floor line. Large furnace volumes have brought about higher efficiencies and enabled the furnace to ignite and completely burn more coal, directly increasing the capacity of the plant.

CUBIC FEET OF FURNACE VOLUME PER RATED HORSEPOWER (10 SQ. FT. BOILER HEATING SURFACE)

Station	Chain-grate stokers	Underfeed stokers
Recent Stations		
American Sugar—Baltimore	2.00	....
Kansas City	2.57	....
Dalmarnock—Glasgow	3.10	....
Barking—London	3.87	....
Calumet	4.45	....
Waukegan	5.75	....
Dodge Bros.	....	2.17
Seward	....	3.24
Colfax	....	3.45
Springdale	....	3.95
Hell Gate	....	4.23
Gennevilliers—Paris	....	4.50
South Meadow	....	4.56
Delaware	....	4.80
Older Stations		
Waterside	....	1.05
Essex	....	1.95
Muscle Shoals	....	2.19
L. Street	....	2.43
Connors Creek	....	2.72

Details of Special Baffles

NEW TYPES OF BAFFLE CONSTRUCTION HAVE SHOWN GOOD RESULTS

INCREASED ratings at which boilers are operated for peak loads are testing more and more severely the baffling of a boiler. These high ratings result in a greater total draft loss through the boiler, consequently in a greater pressure differential between the sides of the baffle. At the same time, a more intense heat is carried farther through the heating surfaces of the boiler.

In order to meet these more severe operating conditions, two advances have been made in the baffling of boilers, first the use of inclined baffles to change the differential of pressure into velocity and second the use of improved forms of construction which can be readily adapted to the inclined form of construction and which at the same time will remain tight under the high temperature conditions.

In developing baffles to meet these requirements, several types of construction have been used, such as flame plates which are usually covered with high temperature cement and interlocking tile; a combination of tile and plastic refractory, and third a monolithic type made entirely of a plastic refractory material.

One baffle construction of the flame type is shown in Fig. 1. With this arrangement, top-connected and bottom-connected castings are used to connect the cast-

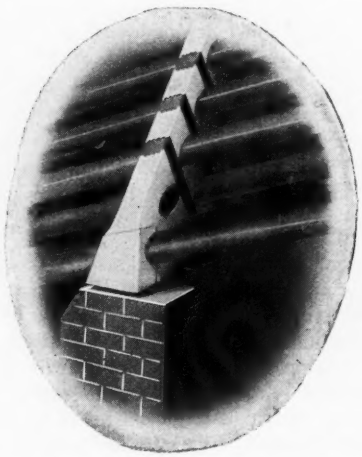


FIG. 2. CORRUGATED TILE AND PLASTIC MATERIAL ARE USED IN THIS BAFFLE CONSTRUCTION

iron flame plates which extend diagonally between the tubes. A coating of hot-blast cement is placed next to these castings and the interlocking tile placed against this. On the other side of the baffle, a layer of the cement protects the flame castings and also aids in closing up any openings.

Other arrangements of this combination metal, tile and high temperature cement baffle wall and even a cast-iron construction without a protective coating have been used.

Another form of inclined baffle which has been used extensively is a combination of tile and plastic cement, as shown in Fig. 2. Through the diagonal alleys between the tubes are placed corrugated tile which dovetail with each other. The spaces inclosed by these tile

and the tubes form a series of pockets which are filled with a plastic cement made of fire-proof materials, which hardens into place much the same as concrete. The pockets are filled by hand and the plastic material tamped into place which assures tightness. The material itself shrinks slightly as it sets and while there is no measurable clearance, the tube is not seized and may readily be withdrawn.

As one of the critical points in baffle wall construction is the joint between the bridge wall of the boiler and the baffle a special footing construction is used. As shown in Fig. 2, this consists of special blocks which are dovetailed and interlocked in place. On top of the bridge wall and in front of the tube blocks is run a stretcher course of fire brick, which serves the double purpose of protecting the tube blocks and sealing any opening between them and the top of the bridge wall, making a gas-tight joint.

With this method of construction, the baffle is entirely self contained and independent of the bridge wall. The joint between the bottom of the tube blocks and the top of the bridge wall can be left with or without a clearance. Tubes can be removed, except in case of serious distortion in which case the blocks can be

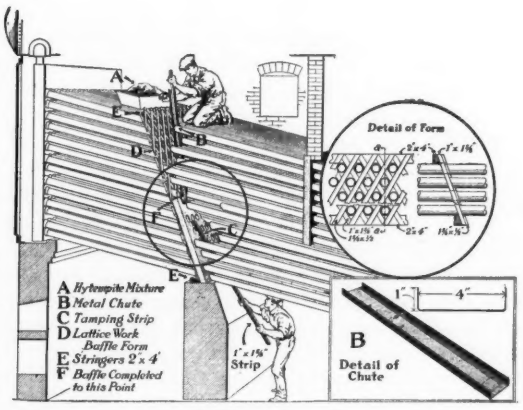


FIG. 3. METHOD OF INSTALLING A MONOLITHIC BAFFLE

broken out. New blocks are then inserted after the new tubes are in place.

Baffles of the monolithic type are made from a variety of mixtures which vary from special high-temperature plastic materials to ordinary Portland cement. There are advantages in the use of the monolithic type of baffle as well as a few disadvantages. The baffle is quite easy to install, as it involves only the erection of some type of form. In cases where the plastic material is of a rather heavy consistency, only one form need be used as the material may be tamped as shown in Fig. 3. In this method 2 by 4-in. stringers are placed across the top of the tubes and 1 by 1⅝-in. slats are placed in the diagonal alleys and nailed or wired to the stringers. A metal chute is then used to feed the plastic material down to the bridge wall. A man stationed beneath the tubes tamps the material as it is placed, using a 1 by 1⅝-in. strip. This strip marked (C) has a shoulder at the end so that the material can be worked snugly around the tubes.

As soon as the material is placed, a drying fire is started, which is light enough so that the forms are not burned out until the material is dried. As the boiler is brought up to pressure, the forms burn out, leaving the monolithic baffle in place.

One operating difficulty which has been encountered with this type of baffle has been due to lack of sufficient mechanical strength to withstand the vibration of tube cleaning. This was particularly true with mixtures which were used at first and which were excellent as refractories but lacked sufficient bonding qualities. The vibration of tubes during cleaning would break away the material where it surrounded the tubes, with result-

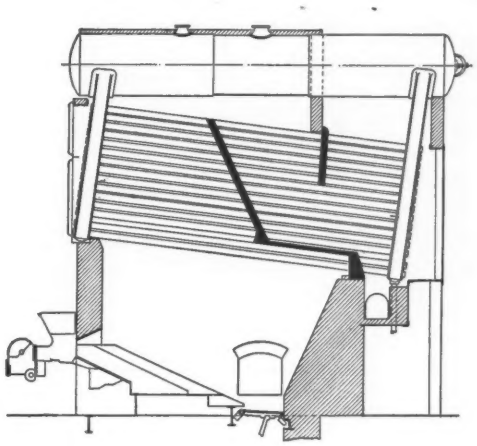


FIG. 4. A MODERN TYPE OF INCLINED BAFFLE INSTALLATION

ing leaks in the baffle. For that reason the bonding qualities have been improved, in some cases by the addition of Portland cement.

In some instances, wire reinforcement has been used to increase the mechanical strength, although this adds somewhat to the difficulties of pouring or tamping. In the case of the combination tile and plastic refractory the tile furnishes this reinforcement.

With all of these types of baffle construction, satisfactory operating conditions have been maintained and the added feature of being able to place the baffle at any desired angle has aided in the improved conditions.

Experience with sectional cast-iron baffles has also been satisfactory according to reports. Burning or distortion has not been marked, although extensive repairs would probably be more difficult than with other types.

Construction of Bridge Walls

Walls Should Be Rugged and Allowance Made for Expansion

ONE important point in furnace design which not only affects efficiency but also increases the maintenance cost of an installation, if not properly laid out, is the bridge wall. The height must be correct for the particular setting and fuel to be used and, at the same time, the construction must be of a type that will not give trouble in operation.

In building a bridge wall, some arrangement must be made for taking care of expansion. If the wall is built in solid to the side walls, the resulting thrust is liable to crack the setting. This may be taken care of

Bridge walls are usually faced with first-grade fire brick for one or two layers, then second-grade fire brick and common brick is used for filler. In some cases, however, plastic refractory is used for the facing.

Usually the bridge wall is of heavier construction than the side walls, particularly for hand-fired furnaces where the wall may get a good deal of battering from the firing tools.

As the height depends on the coal which is used, it is not possible to give any definite figures. For anthracite, the bridge wall in the case of return tubular boilers is higher than for a furnace designed for burning bituminous coal as the volume of gases is larger.

With water-tube boilers, the method of sealing between the top of the bridge wall and the first-pass baffle is important. This space is sometimes packed with asbestos fiber to allow for expansion, one method being shown in Fig. 2 of the preceding article which covers special baffles.

One form of bridge wall construction frequently used with underfeed and chain grate stokers is the overhung type. Reference to the illustrations shown with the articles on water-tube boilers and mechanical stokers will give an idea of the construction.

With the chain grate, one purpose of this overhang is to support any device used for keeping back the fuel bed in order to reduce the air leakage at this point. Sometimes a water back is built in at the overhang which absorbs heat from the hot ash just before it is dumped.

This detail of bridge wall construction is quite important, as considerable difficulty may be experienced in maintaining the overhung portion in good condition unless it is ruggedly built. The supporting steel work should be air cooled by some means, if a water back is not used.

With certain types of setting, the bridge wall is omitted, the rear wall, set in on an angle, taking its place.

Suspended Arches Gaining in Favor

PROPER IGNITION AND COMBUSTION DEMAND CAREFUL CONSIDERATION OF ARCH DESIGN; CONSTRUCTION DETAILS OF ARCHES

BEFORE combustion in itself was considered a branch of engineering, arches of various shapes and designs were installed at random but as the subject was given closer attention, it was discovered that, for certain types of furnaces and boilers, considerable

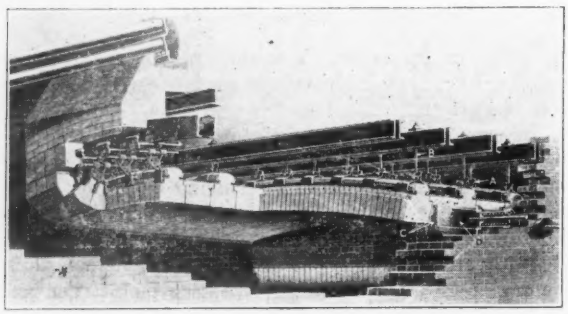


FIG. 1. LATERAL MOVEMENT DUE TO EXPANSION IS TAKEN CARE OF BY THE SKEW BLOCKS (MARKED C) WHICH ARE HELD BY SPRINGS

thought had to be given to the proper design and arrangement of the arch in order to obtain proper ignition and combustion of the fuel.

In the early days, arches were of the sprung type, that is, built in the shape of an arch between the two side walls of the furnace. The sprung arch is still used, although the suspended type is gaining in favor. Naturally, the sprung method of construction creates a pressure on the side walls which is taken up by horizontal beams in the side walls called skew-backs, which are held in place by vertical beams, called back-stays, on the outside walls, these in turn being braced by tie rods.

Because of the circular shape of the sprung arch, the gases tend to collect at the center and are not directed uniformly toward the boiler. Another objection to the sprung arch construction is that in case repairs are required, it is necessary to rebuild the entire arch.

Mainly because of these two reasons the suspended construction, which consists of tile suspended from beams resting on the side walls, was developed. This form of construction permits the use of a flat arch and at the same time gives wider choice in the angle at which it can be placed with respect to the fuel bed.

Although the application of arches varies widely according to the type of boilers, the type of stokers and the fuel to be used, the suspended arch lends itself well to any particular design required.

Chain grate stokers, side feed stokers and front feed stokers require arches in order to secure the best ignition and combustion conditions. Arches are not generally used with underfeed stokers when applied to boilers where the proper setting can be obtained.

Of these various classifications, the application of arches to chain grates is of particular importance, as it has been found that the efficient burning of different kinds of fuels depends on the length of the ignition and combustion arches, their height above and angle of inclination with the fuel bed. Ignition arches for chain grates vary from about 3 ft. 6 in. to 6 ft. in length.

An ignition arch for an overfeed stoker, where fuel is fed from the front, is generally made so that the crown of the arch is horizontal. The length of the arch depends on the type of the boiler and the extension of the stoker in front of the boiler. For eastern coals, the arch is generally about 4 ft. long, the stoker front extending in front of the boiler about 3 ft.

Side feed stokers, especially where a full Dutch oven setting is used, require an arch the full length of this setting. Frequently provision is made for cooling arches of this type by drawing the combustion air over the top of the arch.

Several forms of construction have been developed to meet the requirements of suspended arch construction, all of which, in the main, are based on ideas as to the method of suspension which will stand up under the furnace conditions and facilitate maintenance work.

Several features of design are incorporated in a suspended sprung arch which is built by the American Arch Co. This is independent of the inner lining of the furnace, due to the method of suspension, lateral motion caused by expansion and contraction being taken care of by skew-blocks held in position by springs. In addition to the suspension of the blocks by the special fittings, the arch is built up on a radius similar to the usual sprung construction. Through this arrangement, all of the blocks are under slight pressure, and should a tile crack or spall, the pieces are less likely to drop out.

As will be noted from Fig. 1, short pieces of angle runner engage the heads of the hung tile, these angles being gripped by steel clips which are attached by eyebolts to the channels or angles spanning the furnace. Between these hung tile a special filler tile forms an interlocked construction.

In Fig. 2 is shown the arch built by the Bigelow Arch Co., consisting of a number of slotted tile, each

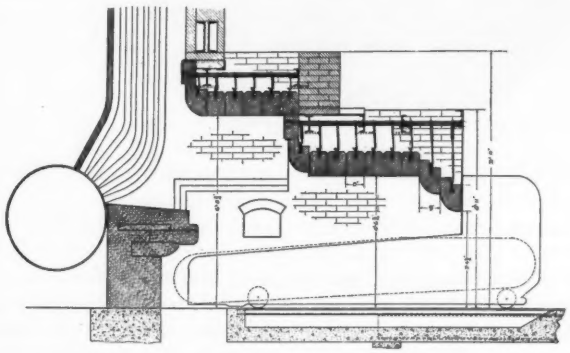


FIG. 2. WHEN A NEW TILE IS INSERTED, TURNBUCKLES ARE USED TO SHORTEN THE HOOKS

independently hung from longitudinal pipes which are supported by transverse beams, the beams resting on the furnace walls or such structure as is best adapted to the requirements. Every tile is, therefore, free to expand in any direction without exerting excessive pressure on the adjacent tile. This method of suspension also makes it possible to remove and replace a tile without disturbing the balance of the arch. When a new tile is inserted in the Bigelow arch, the turnbuckle on the supporting hook is used to shorten the hook until the new tile is flush with the surface of the old arch.

As shown in Fig. 3, the arch which is built by the M. H. Detrick Co. is flat. It consists of center-grooved tile hung from cast-iron hangers, which, in turn, are suspended from structural steel beams, spanning the furnace and resting on the side walls.

With this construction, the arch-bars are hung from the steel cross beams and the tile are hung from the arch-bars. These two points of flexibility make it possible to swing the entire mass of tile 1½ to 2 in. laterally before the tile are grouted in place. Expansion and contraction are provided for by allowing a space at each side, which is packed with loose, dry asbestos. Details of construction of the rear end of the arch are shown in Fig. 4. The apron wall is supported by a shelf casting, independently of the end tile. One shelf casting is keyed to the end of each arch-bar, so that any one casting can be removed without disturbing the apron wall.

In the Illinois flat suspension arch, built by the Illinois Stoker Co., a heavy cast iron beam extends across the entire furnace width and has its end supported on bearing plates in the side walls. This beam serves two purposes: First, it provides a support for the larger part of the curtain wall between the end of the arch and the bottom of the front drum or header. Second, it serves as a support for the rear 2 ft. of arch. Cast on the bottom of this beam at regular intervals are the iron lugs to which are fastened the special cast-iron arch brackets. These brackets are spaced on 6-in. centers

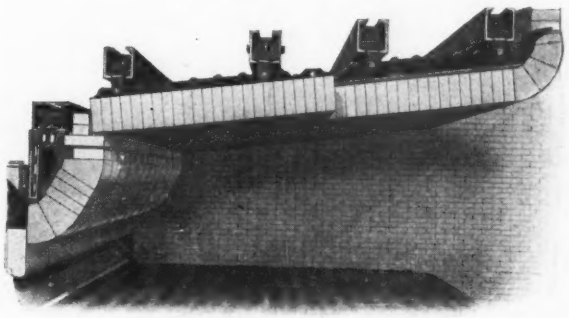


FIG. 3. IN THIS ARCH CENTER-GROOVED TILE ARE HUNG FROM CAST-IRON HANGERS

across the width of the arch, and they, also, serve a double purpose: First, they support the rear 2 ft. of arch tile; and second, the rear end of each bracket is flared out at the top thus providing a flat surface for the support of the remainder of the curtain wall not supported directly by the beam. Any weight on the arch at this point is thereby eliminated. A different construction is used for the support of the remainder of the arch. Each tile has a hole in it large enough to receive a 1-in. pipe. In the erection of arches each row of tile is individually suspended on these pipes. The suspension of the rows of tile is in turn accomplished by beams running at right angles to the position of the rows.

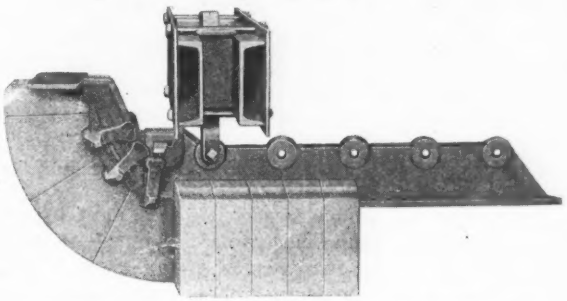


FIG. 4. END CONSTRUCTION SHOWING METHOD OF HANGING TILE

In the Laclede-Christy Co. arch, as shown in Figs. 5 and 6, the weight is supported by heavy beams, not smaller than 10-in., extending across the entire width of the furnace and having bearing plates on the extremities to spread the total weight of the arch over the side walls. This construction prevents thrust on the side walls. Between these beams are bolted cast-iron brackets upon which the arch tile are strung. These brackets are bolted in position and spaced so that all expansion will be

taken care of within the arch. The iron work, with a larger coefficient of expansion, is kept cool so that it will expand evenly with the fire tile below, which has a lower coefficient of expansion, but which necessarily is brought to a much higher temperature. All iron work is so arranged that it is thoroughly ventilated

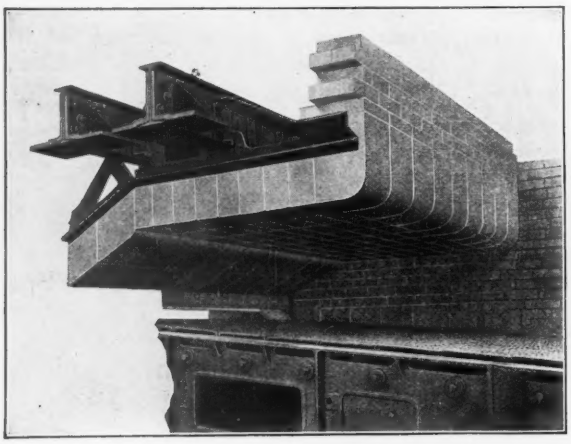


FIG. 5. HEAVY BEAMS HOLD THE SUPPORTING FIXTURES FOR THE TILE

by having small holes through the side walls above the arch.

The arch tile is furnished in either side-hung or center-hung type, each tile hanging individually and perpendicularly, so that there is no strain or pressure from other tiles to cause spalling. The curtain wall is supported from flat tiles resting on the arch brackets entirely independent of the arch tile, thus enabling any section of arch tile to be removed or replaced without interfering with the curtain wall or the balance of the arch.

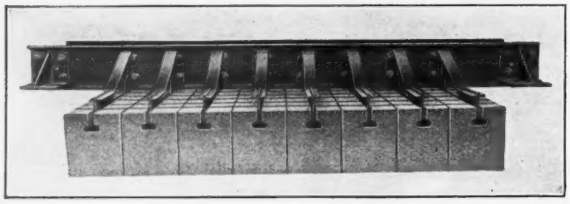


FIG. 6. METHOD OF PLACING CENTER-HUNG TILE

In reality, the double suspension arch built by the Liptak Fire Brick Arch Co. is two arches in one—a main arch exposed to the furnace fire and a reserve arch above, from which the main arch is suspended. This reserve arch protects the supporting iron work from the furnace heat and makes it possible to burn out practically all of the main arch before repairs are necessary.

Use of a reserve arch also permits a better seal to the furnace roof and prevents the hot gases from circulating around the refractory blocks or air infiltration through the arch. A proper seal with the side walls and front wall is effected by extending the arch several inches into each wall and by using an asbestos expansion joint, which acts as a cushion, to allow for proper expansion of the refractory materials when the arch is put in service.

The curtain wall above the ignition arch as shown in Fig. 7 is supported by cast-iron plates which slide into slots provided in the cast-iron hangers, while the curtain wall above the main arch is either supported by a plate resting on the end of the cast-iron hanger tips or by a plate which is attached to a separate I beam,

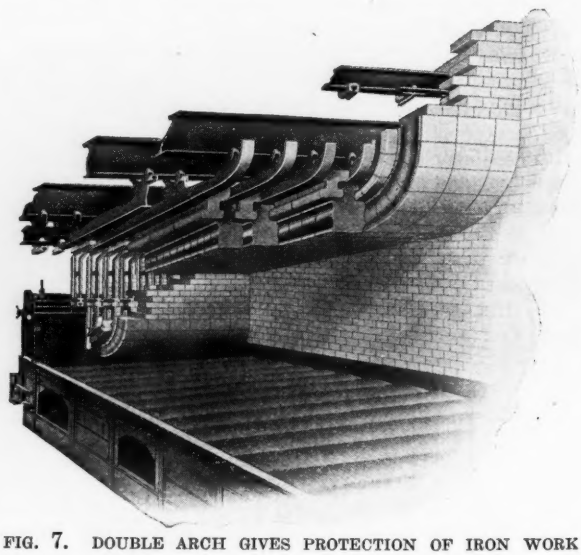


FIG. 7. DOUBLE ARCH GIVES PROTECTION OF IRON WORK

either being bolted to the beam or supported by the use of cast-iron brackets.

In the suspended arch built by McLeod & Henry Co., any single block can be removed from underneath or above, without disturbing any other block or the suspension. Reference to Fig. 8 shows that the blocks in the flat part of the arch are of one size, interchangeable and suspended in parallel rows from the lower flanges

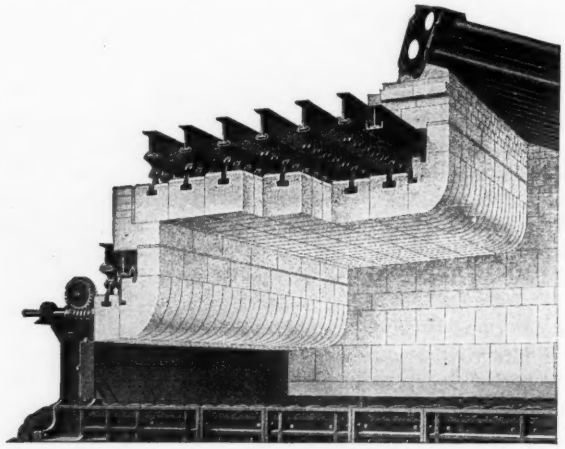


FIG. 8. GAS-TIGHT WOOL CUSHIONS AT JUNCTION OF ARCH AND BOILER WALLS ALLOW FOR INTERNAL EXPANSION

of I beams, each block having its own hook and rocking link.

This suspension is flexible, each block hanging straight downward without imposing side thrust upon its neighbors, and each block being free to move laterally in any direction. With all blocks assembled, the mass as a whole can move sidewise in any direction to com-

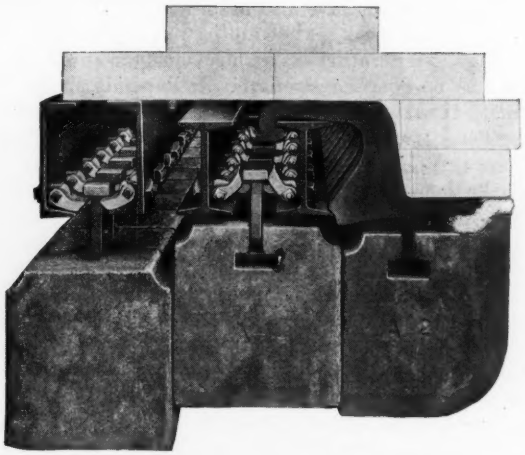


FIG. 9. CLIPS LOCK THE TILE IN POSITION

pensate for internal expansion, which is made independent of that of the boiler walls by gas-tight asbestos-wool cushions at all junctures of the arch proper with the other boiler parts.

In the case of arches set on a slope, flat bottom surface with straight downward suspension is maintained by beveling the bottoms of the blocks to correspond with the slope, and by proper adjustment of the up-and-down position of the block. The latter is accomplished by the use of different thicknesses of bearing plates to give different heights to the supporting beams.

One feature of the National arch, which is built by the M. A. Hofft Co., is the use of a hinge for locking the tile in place. As will be noted from Fig. 9, each tile hangs on a separate cast-iron bolt. To insert a tile, all that is necessary is to put the solid cast-iron bolt in the slot of the tile and shove the tile and bolt up until the bolt head passes between the two halves of the hinge clip. Then the tile is let down until the clips engage the bolt head.

Each row of tile is placed on separate pairs of channels or I-beams, resting on the side walls, so that the weight of the arch is evenly distributed on the side walls.

Waite & Davey arches are hung with pipe hangers having tee connecting ends to slip into slots made in the blocks, as illustrated in Fig. 10. Tees are used for the connections to allow a free circulation of air. The projecting ends of the pipe hangers are threaded, and the blocks are suspended from channel-iron cross beams, as shown, by the use of floor flanges and nuts. By this means of suspension, a flat fire side of the arch is readily obtained. Each tile or block in the arch is a separate unit and, by making the hangers of sufficient length and placing the suspension bar high enough above the arch, any one unit can be readily replaced without cutting the boiler off the line. The design of the curtain wall is shown in Fig. 10 with a detail of the upper block at A. The method of supporting this wall is also clearly shown.

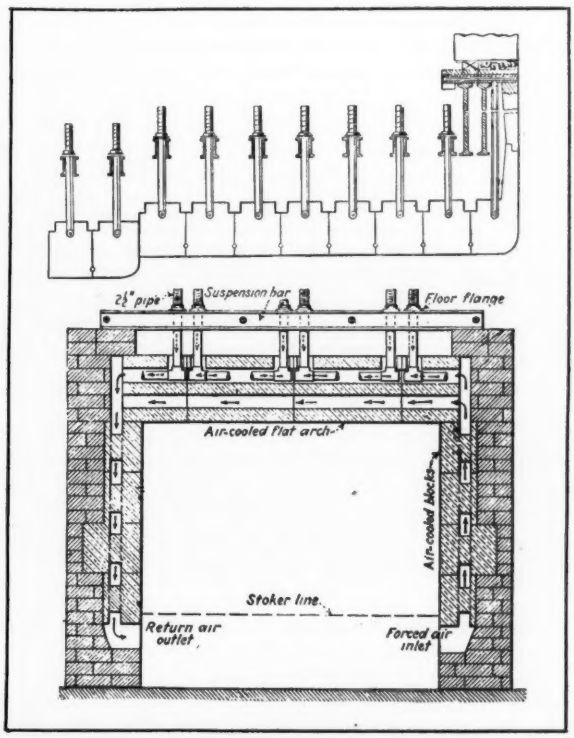


FIG. 10. SUSPENDED ARCH IS AIR COOLED

Improvements in Furnace Lining Material

SEVERAL METHODS USED TO REDUCE MAINTENANCE COST OF LININGS

OIL, pulverized fuel and higher ratings with stoker-fired furnaces, resulting in higher furnace temperatures have made the problem of securing a furnace lining which will stand up under the operating conditions, a problem of no little importance. While fire brick may even yet be said to be the mainstay of the furnace, many new methods have been utilized to reduce the cost of furnace maintenance. With the introduction of a part of the combustion air through blocks below the fuel line in stoker-fired furnaces; the use of special mixture blocks of large size to reduce the number of joints; the use of monolithic linings and the use of high temperature cements to cover ordinary fire brick, the difficulties have been largely surmounted.

In the past year, many installations have been made in which are used perforated blocks of one type or another through which a part of the combustion air is introduced. In this way, the temperature of the adjacent fuel bed has been lowered below the fusing point of the clinker and the walls have been protected against this source of damage. In Fig. 1 is shown a typical layout of such an arrangement.

One of the weaknesses of the ordinary fire brick furnace lining has been in the number of joints exposed to the high temperatures. The best of fire clay cement, which acts more as a flux and a filler than a bonding element, is softer and more susceptible to damage than is the brick surface. The joint filling may melt or crumble out from the heat alone, or it may fuse with the clinker and the surface layer be pulled from place when the clinker is removed. Once the outer joint surface is impaired, the inner filling disintegrates rapidly and erosion and abrasion eat deeper and deeper into the joint.

The rate of destruction increases progressively to include breaking off of edges and corners and displacement of brick and, finally, neglect produces leakage of cold air through the setting with resulting decrease in capacity and fuel loss.

For these reasons, larger blocks have been developed in order to reduce the number of joints and to present

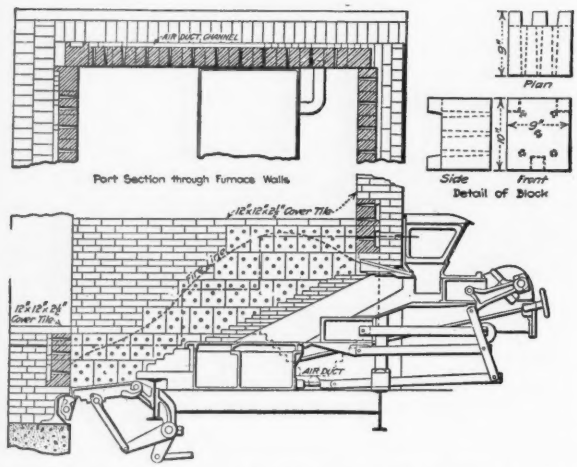


FIG. 1. INTRODUCTION OF AIR THROUGH WALL BLOCKS REDUCES CLINKER DAMAGE

large refractory surfaces to the fire. These large blocks are accurately made so that they may be laid with thin, gas-tight joints which can be sealed with a small amount of filler.

Another approach to this problem has been in the development of monolithic linings. This form of lining consists of a stiff plastic material which is tamped into place and then vitrified with a slow fire.

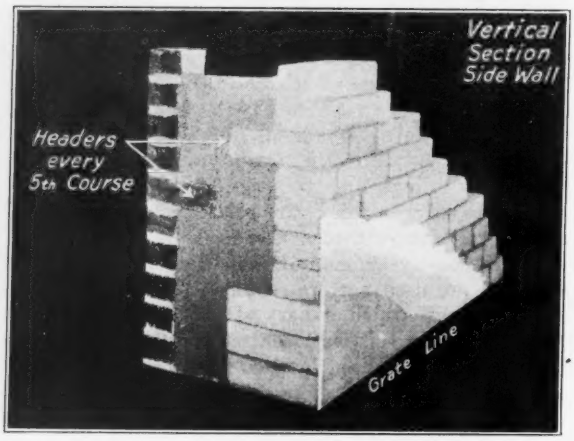


FIG. 2. USE OF GROUND FIRE BRICK AND HIGH TEMPERATURE CEMENT IN WALL CONSTRUCTION

With this lining, the plastic material is placed next to the insulating material and next to this is the outside brick which is used for its strength and as a support and protection for the insulation and refractory. Often the outer brick is covered with an impervious paint which prevents air from seeping through the brick. As the jointless lining seals up the whole inside of the furnace, the entry of air through it is prevented.

Improvements have also been made in the method of laying up fire brick and of aiding in its protection from the high temperatures. As previously mentioned, fire clay has no bonding strength. It depends on the high heat of furnace temperatures to fuse the brick and clay together. It cannot extend through the entire thickness of the refractory wall. Moreover, fire clay joints have not the same relative expansion and contraction as the brick when temperature changes occur.

To overcome these difficulties, a number of high temperature cements have been developed which combine refractory and bonding qualities. The bricks are carefully selected for uniform size and laid with the use of the high-temperature cement. Then, as a rule, the entire lining is washed with the cement or, in some cases, is given a coating about 3/8 in. thick, of a plastic high-temperature cement and then washed.

With such treatment, good results have been obtained with furnaces lined with fire brick.

Another development has been the use of a mixture of ground fire brick and high-temperature cement for repairing furnace linings, for use as a protective coating by applying it with a cement gun and also for use as a filler material in building up furnace walls. In Fig. 2 is shown an example of how ground fire brick may be used.

Condenser Tube Failures

MATERIALS AND PROCESSES OF MANUFACTURE NOT CHIEF FACTORS

IN THE Dec. 1, 1923, issue, on page 1201, was published an article by William R. Webster, entitled Factors Affecting Condenser Tube Failures, which was a valuable contribution to the literature on this subject. Unfortunately, the sub-title as printed gave a wrong impression of Mr. Webster's deductions.

While the qualities of metals for tubes and requirements of manufacture to insure best results were discussed at length, it was shown by Mr. Webster that conditions under which the tubes are used and lack of proper care in design and operation are principal factors in reducing the life of tubes. He stated that exacting specifications as to materials and manufacture cannot be relied on as remedial agencies to any material degree, as there are no records of experience to show that any properties of a condenser tube, beyond those incident to good workmanship, can be predictably related to its service endurance. Specifications as adopted by the American Society for Testing Materials, are believed to cover the requirements of best manufacturing practice and their general adoption would benefit the condenser industry.

Mr. Webster urged that careful investigation be made of operating conditions under which failures occur, keeping records of temperature, water velocity, shutdowns, cleaning procedure, character and position of corrosion, etc., so that progress may be made in determining the causes of failures and removing them.

THE GREATEST care must be taken in cutting a boiler in on the line with others in service. When the pressure is the same as the line pressure and with the piping and valves drained of all water, crack the stop valve, and if everything sounds good, slowly open the valve until fully open.

Proper Grate Design Important

GRATE AREA, AMOUNT OF AIR SPACE AND TYPES OF BARS MUST BE CONSIDERED

IN ORDER to secure the best operating conditions with hand-fired stationary grates, it is necessary to consider carefully the various factors which influence the grate area, the amount of air space required and the type of grate bar which should be used. Assuming that the boiler has been selected, the determination of the grate area is based on the coal available and the draft required. The curves in Fig. 1 show the draft which is necessary for burning different coals at various rates of combustion.

Certain draft is required to overcome the resistance of the boiler and this loss, in terms of pressure drop, is known fairly closely and may be obtained from the boiler manufacturer. This must be subtracted from the total draft to determine that available for the fuel bed.

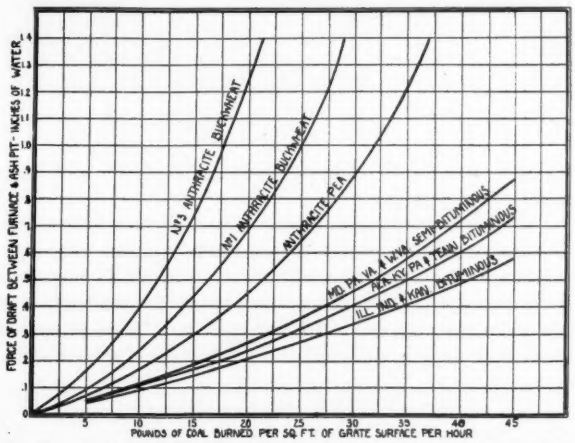

FORCE OF DRAFT BETWEEN FURNACE & ASH PIT - INCHES OF WATER
POUNDS OF COAL BURNED PER SQ. FT. OF GRATE SURFACE PER HOUR
NO 3 ANTHRACITE BUCKWHEAT
NO 1 ANTHRACITE BUCKWHEAT
ANTHRACITE PEA
MD. PA. VA. & W.VA. SEMI-BITUMINOUS
KY. PA. & PEAN. BITUMINOUS
ILL. IND. & W.KY. BITUMINOUS

FIG. 1. DRAFT REQUIRED AT DIFFERENT COMBUSTION RATES FOR VARIOUS COALS

When the type of boiler is known, the overall efficiency can be approximately assumed. Knowing the capacity of the boiler, the number of heat units required at the assumed efficiency may be determined and from this the pounds of coal required per hour. Dividing the number of pounds of coal which must be burned per hour by the rate of combustion taken from the curves in Fig. 1, gives the total grate area in square feet.

For estimating the grate area in a somewhat similar way, the following formula is sometimes used:

$$\text{Grate surface} = 33{,}480 \text{ hp.} \div B\ K\ E$$

in which hp. is the rated horsepower of the boiler; B is the heat value of the fuel in B.t.u. per lb.; K is the rate of combustion in lb. per hr. per sq. ft. of grate and E is the combined efficiency of boiler and furnace.

Some authorities state that, for anthracite and for poor varieties of bituminous high in ash, with ordinary furnaces, not less than ⅓ sq. ft. of grate surface should be furnished per horsepower with ordinary chimney draft (not exceeding 0.3 in. of water) at the damper. A smaller ratio of grate surface may be allowed for high-grade bituminous coal and for forced draft. Manufacturers usually provide about 1 sq. ft. of grate surface for every 45 sq. ft. of heating surface.

With coals high in ash, especially if the ash is easily fusible, large grate surface and a slow rate of combustion are required, unless means such as shaking grates are provided to get rid of the ash as fast as it is formed.

After the grate area has been determined, the next step is to decide upon the amount of air space required. The usual practice is to allow from 30 to 50 per cent of the grate area as air space, although for coal which clinkers, the large air space is preferable. Extra space can do no harm, if it is so arranged as to prevent unburned fuel from dropping through the grate. If the space through the grate is found to give more air than needed, the draft can be cut down and thus the air supply adapted to the amount of fuel being burned. If, on the other hand, the air space is too small, it is sometimes

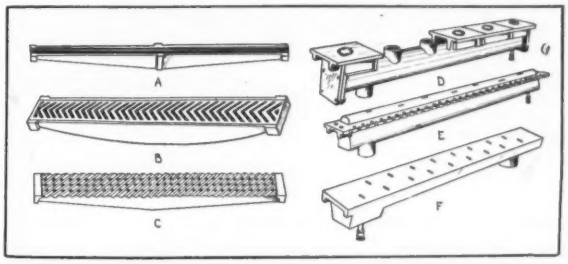


FIG. 2. SOME TYPES OF GRATE BARS WHICH ARE USED

a difficult matter to get sufficient draft to pull the required air between the grate bars.

As the size of the openings between or in the grate bars, which make up the total air space, depends on the kind of fuel used, this is the next point for consideration.

For No. 3 buckwheat coal, ⅛-in. openings are usually allowed; for No. 2 buckwheat, ¼-in.; for No. 1 buckwheat, 5/16-in.; for pea coal, ⅜-in.; for stove coal, ½-in.; for egg coal, ¾-in.; for mine run bituminous, ½ or ⅜-in., and for slack, about ¼-in. Anthracite screenings, culm, etc., require grates with pin hole opening ⅛ to 3/16 in. with forced draft of from 2 to 3 in. For wood slabs, air spaces of ¾ in. are usually provided; for sawdust, ¼ to ⅜ in. and for shavings, ½ to ⅝ in.

Grate bars are usually made in sections 3 ft. long, 3 to 6 in. deep at the middle and about 1 in. deep at the ends. The total length of grate is limited in hand-fired boilers by the ability of the fireman to keep them covered with coal at the far end of the furnace. Grates for anthracite may be 10 to 12 ft. long, while the greater difficulty of handling the fire usually limits grates for bituminous coal to from 6 to 8 ft. long. Grates usually pitch toward the back of the furnace from ¾ to 1½ in. per ft. of length.

Many types of grate bars have been designed according to varying ideas as to the best methods of handling different fuels. In Fig. 2 are shown some of these types. The bar shown at A is the common or garden variety of grate bar while B is the herringbone type. C is a bar which has been designed for sawdust or wood refuse. Grate bars D, E and F are of the hollow, blast type. Bars of this kind are for use with sawdust, tan, palmetto fiber, rubber gayule, bagasse, coal screenings and other fuels which are hard to handle on ordinary grate bars.

Rocking and Dumping Grates

PRINCIPLES OF OPERATION WITH GENERAL DESCRIPTION AND DETAILS OF MAKES

IN HAND-FIRED plants, the use of shaking and dumping grates presents a distinct advantage over stationary grates in that the fireman can clean the fires without opening the furnace doors and allowing the entrance of large quantities of excess air, which results in waste of fuel and consequent low efficiency. With shaking grates, too, the manual labor required is less than with stationary grates. For the installation which is too small to warrant the installation of automatic mechanical stokers, the shaking grate or the hand stoker is found satisfactory.

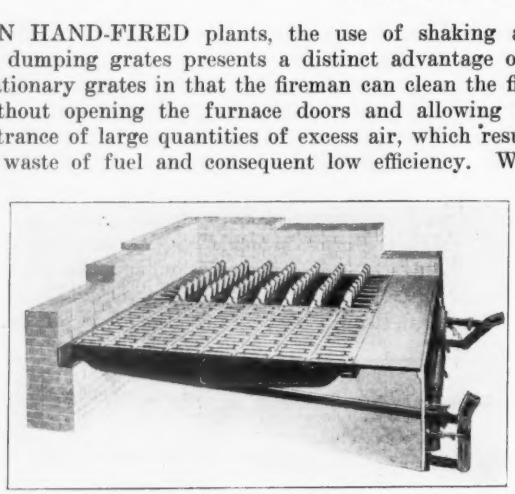


FIG. 1. ARMSTRONG INTERLOCKING SHAKING GRATE

There are upon the market a large variety of mechanical grates which may roughly be classified according to whether they are of the plain shaking type or of the dumping type. In either type, the grates are built up of a number of movable elements which are operated from the front of the furnace by means of one or more hand levers. In some cases, all elements of the grate are operated at one time by a single lever; while in other cases, only certain sections of the whole grate are operated at one time.

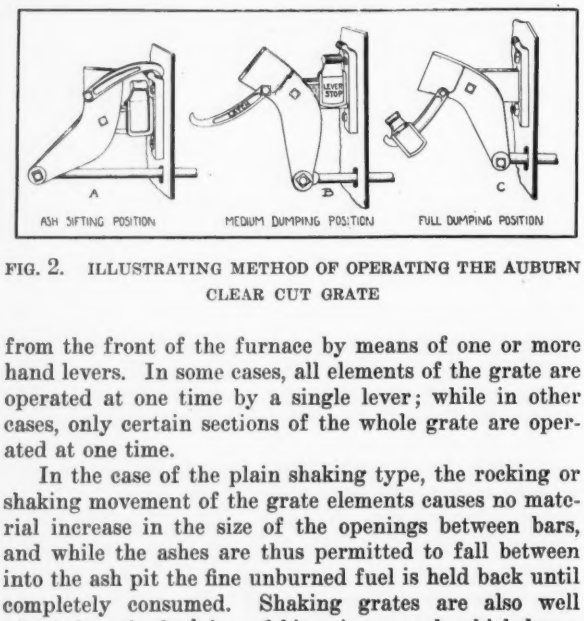


FIG. 2. ILLUSTRATING METHOD OF OPERATING THE AUBURN CLEAR CUT GRATE

In the case of the plain shaking type, the rocking or shaking movement of the grate elements causes no material increase in the size of the openings between bars, and while the ashes are thus permitted to fall between into the ash pit the fine unburned fuel is held back until completely consumed. Shaking grates are also well adapted to the burning of bituminous coal, which has a natural tendency to coke. With fuel of this kind, the shaking or oscillating movement of the grate removes the ash as fast as it is formed and the air passages through the fuel bed are kept open.

In mechanically operated grates of the dumping type, as a rule, the grate surface can be cleaned by shifting the fire and dumping one section at a time. If it becomes necessary to remove the fire, it can be done instantly by dumping the entire fuel bed into the ash pit. In some makes, special provision is made for breaking up large clinker formation without allowing the medium size, unburned fuel to pass through the grates. This is of particular advantage in burning low grade coal and screenings carrying a high percentage of ash and noncombustible matter.

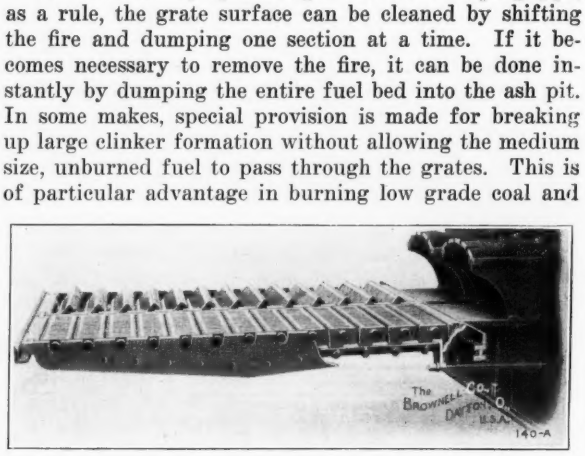


FIG. 3. THE BROWNELL ROCKING AND DUMPING GRATE

While the details of construction of the various makes of rocking and dumping grates on the market vary considerably, the principles of operation in all of them are similar. The highly important point for any type of grate is that the materials of which it is constructed must be able to withstand the heat of the furnace without serious warping. Suitable provision must be made to allow for expansion of the grate bar elements without having them bind.

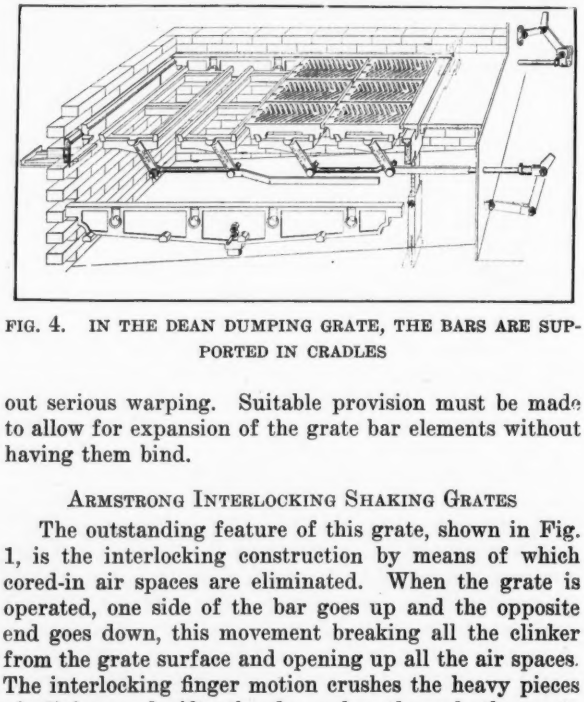


FIG. 4. IN THE DEAN DUMPING GRATE, THE BARS ARE SUPPORTED IN CRADLES

ARMSTRONG INTERLOCKING SHAKING GRATES

The outstanding feature of this grate, shown in Fig. 1, is the interlocking construction by means of which cored-in air spaces are eliminated. When the grate is operated, one side of the bar goes up and the opposite end goes down, this movement breaking all the clinker from the grate surface and opening up all the air spaces. The interlocking finger motion crushes the heavy pieces of clinker and sifts the fine ashes through the grate without disturbing the fire.

Latches are provided on the shaking mechanism so that either the shaking or the dumping action may be

had. The grate is manufactured by the Armstrong Manufacturing Co.

Auburn Clear-Cut Grates

The Auburn Clear-Cut grate of the Auburn Foundry Corporation is of the interlocking type and is provided with both the shaking or rocking feature and the dumping arrangement. The grate bars are of one piece construction, suspended between cast-iron side and center frames, which are all locked together without bolts or rivets, making it extremely simple to erect. Bearing blocks and keys lock all rocking grate bars into the bearings.

An interesting feature of the Clear-Cut grates is the arrangement provided for operating. This, as shown in the diagrams, Fig. 2, consists of an operating lever with a latch, and a lever stop. The ash sifting movement is obtained by moving the lever handle towards the furnace front with both the lever stop in place and the latch secured. To obtain the medium dump opening, the latch is lifted back as shown in Fig. 2B and to obtain the full

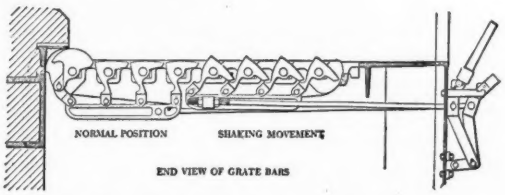


FIG. 5. THE ERIE CITY SHAKING GRATE

dumping opening, both the latch and the lever stop are lifted as shown in Fig. 2C. This gives a 5-in. dumping clearance between the rocking bars.

Brownell Rocking and Dumping Grates

The Brownell Co.'s rocking and dumping grates, as shown in Fig. 3, are simple in construction, and are fitted with a shaking bracket so arranged that the grates can be locked in flat position, or set so as to shake, or at still another setting to dump the fire completely. The grate-bar ends rest upon angle bars at each end of the furnace and shaking rod is connected to lugs on the grate bars by small pins secured in place by cotters. The grate bars are castings provided with a number of slots for the admission of air.

Dean Dumping Grates

As may be seen in Fig. 4, which shows the details of construction, the bars of this grate are supported on a cradle, which in turn is supported by the bearing bars. The cradles tip in tandem to an angle of 65 deg., which dumps the bars free of all ash and clinker. When in normal position, the cradles rest at the rear end on beveled stops which are a part of the side and center carriers. All grate bars are of heavy rectangular section made with either diagonal or herringbone slots.

Dean dumping grates are made by Washburn and Granger, Inc., and are built in banks, each bank dumping in one or more sections. When cleaning fires, the live coals on the front sections are pushed back onto the rear sections; the front sections are then dumped, thereby freeing themselves of all ash and clinker. The front bars are then returned to normal position and all live coals pulled forward onto the front sections. The rear sections are then cleaned in the same manner.

This company also makes a shaking grate which is especially well adapted for burning bituminous coal having a natural tendency to coke. In this grate, the bars are given a shaking or oscillating movement which allows ash to be removed as quickly as formed and the air pas-

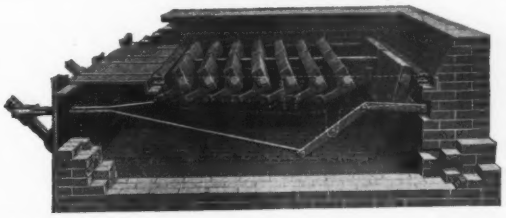


FIG. 6. A VIEW OF THE KELLY SHAKING GRATE SHOWING REAR DUMP PLATE IN CLEANING POSITION

sages through the fuel bed are thus kept open at all times.

Erie City Shaking Grate

In the grate shown in Fig. 5, which is made by the Erie City Iron Works, the design has been made as simple as possible. The use of a large number of small parts has been avoided and as a consequence there are no com-

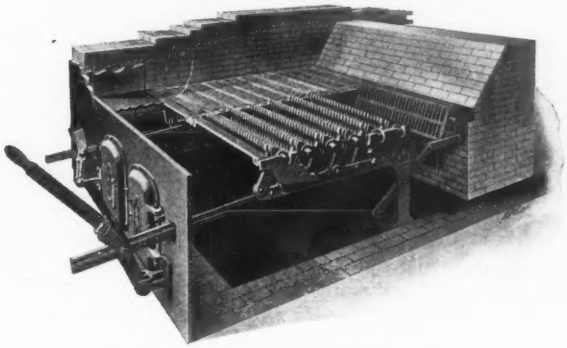


FIG. 7. THE LOCO SHAKING GRATE

plicated fastenings to fall out. The bars are of simple one-piece construction and are made with a double lug at the lower end which receives the shaking bar as may be seen in the illustration, Fig. 5. A wrought iron pin is passed through the shaking bar and the two lugs on the grate making a rigid connection. The action of this grate is apparent from the illustration.

Kelly Rocking and Dumping Grate

Figure 6 is a view of the Kelly Foundry and Machine Co.'s Style B grate in the dumping position, this grate having both the rocking and the dumping features. The rocking motion is confined to a certain limit by a locking device which eliminates the possibility of wasting fuel or dumping the grates in the rocking action. A steady fire can be maintained by rocking the grates and keeping the air spaces open. The grate bars are of one-piece construction with a suitable proportion of air space incorporated in the bar itself.

The bars are supported on side and center bearing-bars, which in turn are connected at the ends by tie bars so as to make the whole grate self-contained. The bearing ends of the center and side bearing-bars are so constructed as to rest on the regular standard front and

rear grate rests. A triple capacity rear dumping grate is provided which is operated independently of the front sections.

Loco Shaking Grate

This grate, manufactured by the Casey-Hedges Co., is of rugged construction and is simple in action. The shaking and dumping action is controlled by a long shaker rod drilled with a number of small holes. By locking the operating lever into these various holes, the

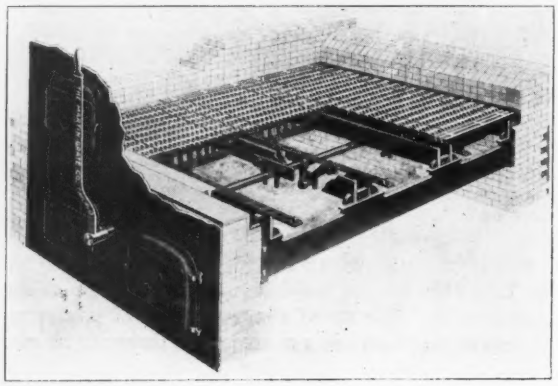


FIG. 8. THE MARTIN ROCKING AND SHAKING GRATE

action of the grate may be changed from sifting to dumping or to normal position as desired.

The Martin Rocking and Shaking Grate

An unusual feature of the Martin Rocking and Shaking Grate, manufactured by the Martin Grate Co. and illustrated in Fig. 8, is the arrangement of the bars—they are placed lengthwise, not across the furnace as in other types. Another feature is the design and method of arranging the grate bars, the details of which may be seen in Fig. 9. These bars are narrow and are spaced rather close together. When the shaking operation takes place, the bars scrape the bottom of the fuel bed, so that

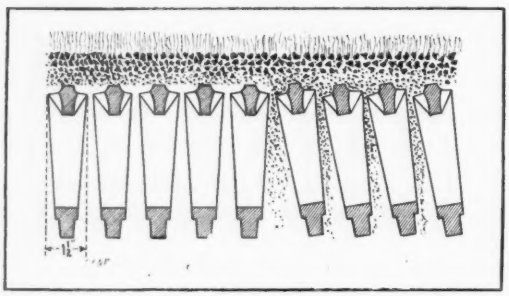


FIG. 9. SHOWING ACTION OF MARTIN GRATE

only that part of the fuel which has been completely reduced to ashes can slip through the bars. The bars are supported, pendulum fashion, with the weight at the bottom, so that gravity always tends to keep the grate level. The fireman can release the shaker handle at any point, and the grate will return to its normal position. This prevents the possibility of leaving the bars in an inclined position and exposing the fingers of the bars to the fire. The grate is adjustable for varying fuels, loads and drafts, and operates with fuel bed varying from 2 up to 15 or 20 in. in thickness

McClave-Brooks Grate

In Fig. 10 a detailed view of a shaking and dumping grate made by the McClave-Brooks Co. is shown. This is known as their type 2A grate and is adapted for the

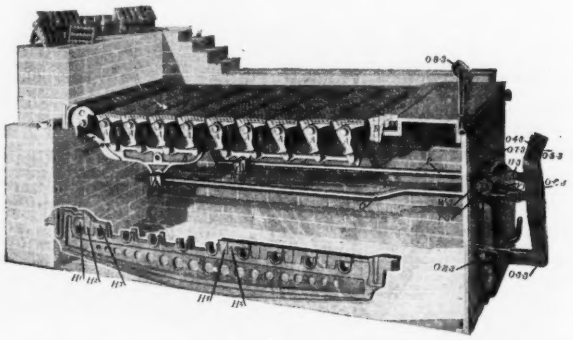


FIG. 10. VIEW OF THE MC CLAVE-BROOKS SHAKING AND DUMPING GRATE

burning of bituminous, semi-bituminous and lignite coals. In this grate, the bars are made with removable sectional tops having shanks which are mounted in sockets in the pendant body portion of the bars. A soft steel pin is cast in the lower end of the shank and is bent over to lock each top securely in place. In this construction

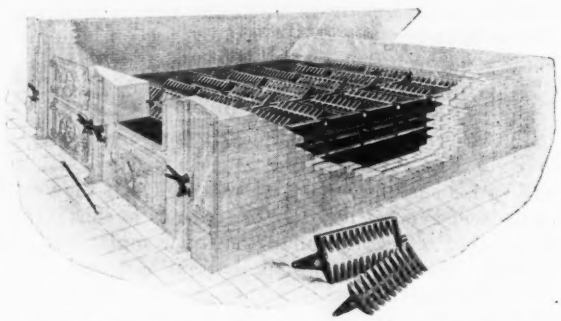


FIG. 11. MURRAY TRIPLE ACTING ROCKING GRATE

if one of the top sections should be broken, only one sectional top would have to be replaced instead of a whole new bar, as is the case when the top and body portion of the bar are cast integral.

In operating this grate, the shaking movement does not increase the size of the openings and no large particles of fuel can pass through. The shaking movement does, however, break up a soft coal fire when there is little or no clinker formed. The cut off or dumping movement removes the ash and clinker uniformly from front to rear when free burning fuel is used.

Murray Triple Acting Rocking Grate

This name is used because of the three-fold action. The grate bars, as may be noted from the illustration, are supported in frames which also serve as part of the total grate surface. This arrangement provides the three-fold action—the grate bars act by themselves, the frames by themselves and one against the other. These grates are particularly adapted for the burning of low

grade coal and screenings carrying a high percentage of ash and non-combustible matter which forms clinkers. The clinkers that form on the grate can be broken by shaking the grate bars, leaving the frame stationary and so not opening holes to let live coal through to the ash pit. Heavy clinkers can be broken by shaking the frame against the grate—an action that will break any clinker formed on the grates and yet let nothing but small pieces through. In cleaning fires after the clinker is broken, shaking both frame and grate together opens a straight dump to the ash pit. The grate is made by the Murray Iron Works Company.

Hand Stokers Reduce Operating Labor

FIELD OF APPLICATION, GENERAL DESCRIPTION OF ACTION, DETAILS OF CONSTRUCTION OF DIFFERENT MAKES

HAND STOKERS HAVE been developed to meet the need for an apparatus which would have many of the advantages of mechanical stokers, yet would be suitable for small installations where the purchase cost of mechanical stokers would be too great. With a good hand stoker, the capacity of a boiler as rated to be developed by hand firing may be exceeded by 30 to 75 per cent. Cleaning fires is less difficult and efficiency of combustion improved. The cost of labor also, will be reduced.

Most hand stokers employ a method of overfeed stoking in which the coal is pushed in at the top of a sloping grate and coked by the aid of a fire-brick arch. The coal is moved from top to the bottom by various motions of the bars aided by gravity. Clinker collects at the bottom, and is dumped into the ashes by the action of some sort of a dumping plate. Coking is confined to the top of the furnace.

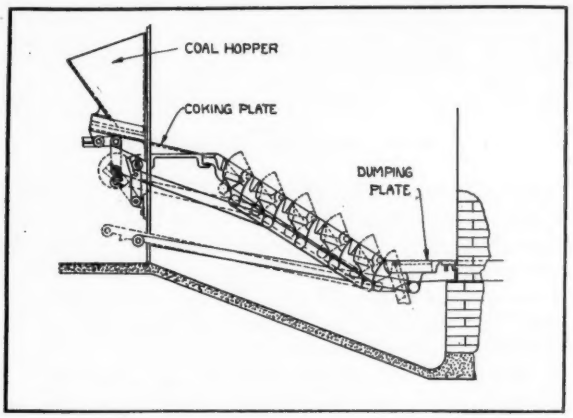


FIG. 1. SECTIONAL VIEW SHOWING ARRANGEMENT OF PARTS IN THE ARMSTRONG HAND STOKER

ARMSTRONG INTERLOCKING STOKER

In the Armstrong stoker, one-half the grate area is stationary and one-half is movable. The movable half passes up through the stationary half making all air spaces between the grates. The slightest movement of the grates instantly opens up all air spaces and allows the passage of a regular and continuous air supply through the fuel bed. The fingers of the movable grates are circular in shape so that when they are raised to full height, the size of the openings is not increased and unburned coal cannot drop through into the ash pit. This stoker is made by the Armstrong Manufacturing Co. and can be furnished either with or without a feed hopper as may be desired.

THE AUBURN HAND STOKER

This stoker is made by the Auburn Foundry Corporation and is shown in Fig. 2. Coal is piled upon coking plates either by hand or directly from a hopper type feeder at the front of the furnace. Plungers or pusher rams immediately behind the coking plate are operated as needed and serve to push the pile of coked coal onto the movable units of the stoker. These movable units are operated only about every third operation of the plungers and travel over the stationary bars, which are located between the movable units, in such a way as to advance the fuel bed a definite amount with each opera-

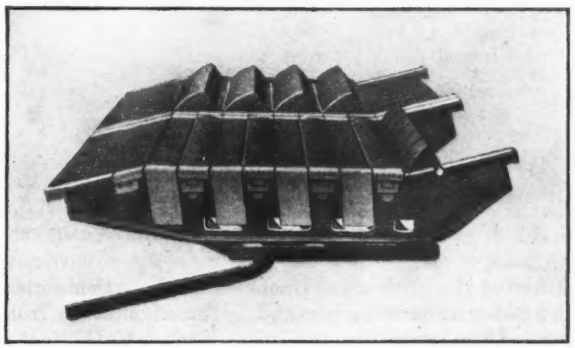


FIG. 2. THE AUBURN HOPPER FEED HAND STOKER

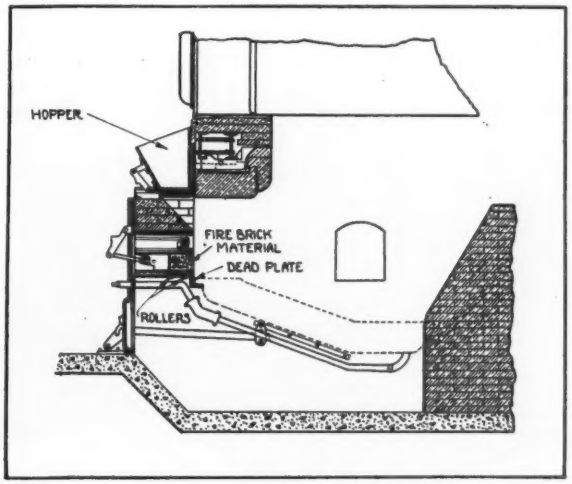


FIG. 3. DIAGRAM SHOWING SECTION THROUGH THE AUBURN HAND STOKER

tion. A positive travel of the fuel bed toward the rear of the grate is thus secured. At the rear of the stoker is located a counter balanced dump plate which not only serves to discharge the ashes into the ash pit but also wings upward so as to break the clinker crust from the bridge wall.

The Cokal Chainless Stoker

In Fig. 4 is shown a view of the Cokal hopper feed stoker made by the Cokal Corporation. This also is a

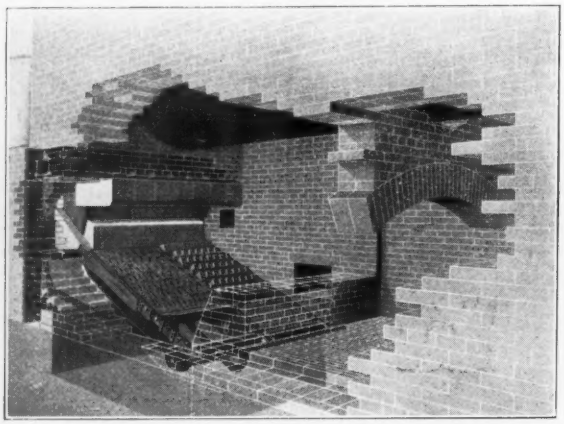


FIG. 4. THE COKAL HOPPER FEED CHAINLESS STOKER

stoker of the progressive combustion type. Coal enters the stoker from a hopper and is forced into the front part of the furnace by the feeder block. As the fuel is gradually heated, first the volatiles are driven off and then as the fuel reaches the zone of more intense heat it is burned as coke. Each time the stoking lever is moved, the synchronous motion of the stoker bars distributes the coked fuel evenly over the stoker surface. The construction of the stoker bars is such that the distribution of the fuel is sideways as well as rearward.

FIG. 5. MC CLAVE HOPPER FEED HAND STOKER, SHOWING KICKER MOVEMENT. THE FRONT AND REAR SECTIONS CAN BE WORKED INDEPENDENTLY OR AS A SINGLE UNIT

During the stoking process, the alternate intermeshing fingers of the stoking bars form diagonal paths of travel for the fuel which insures constant leveling of the fuel bed. At the rear of the stoker, the fuel accumulates on a dump plate from which it may be discharged into the ash pit. A retarder plate is provided which rises when the dump plate is dropped, so as to retain the live coal on the stoker while the ash is being discharged.

The dump plate, in swinging back, gives a back slap action which crushes all clinker.

McClave Hopper Feed Hand Stoker

This stoker, which is made by the McClave-Brooks Co., is provided with an inclined grate for the progressive combustion of the fuel from front to rear of the furnace.

The grates are made in one or more rows as required, the grate proper having alternate rows of stationary bars and kicker bars, both of which are made with re-

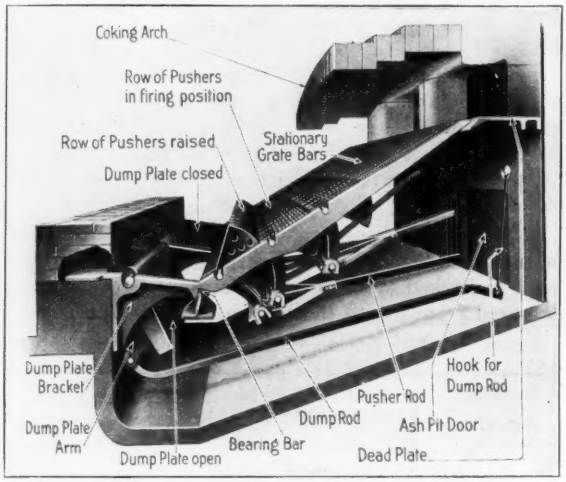


FIG. 6. NATIONAL HAND STOKER

movable sectional tops with shanks and are mounted in sockets in the pendant body portion of bars. The kicker bars are movable and are operated by latches and twin levers which permits a divided kicker movement in either row of grates or a full kicker movement of all rows, thus enabling the operator to work any one section or the entire stoker at one time.

McClave hand stokers may be furnished with or without hopper feed as desired. The former type has coal magazines or hoppers into which fuel may be fed by chutes from overhead bunkers or by traveling larry or, if necessary, by hand. At the bottoms of these magazines are located the coking plates which extend completely across the front of the furnace and directly under the main arch. Coal is deposited on the coking plates from the bottoms of the hoppers or magazines and is then fed onto the inclined grates by plungers or pushers which always feed the same quantity at one movement. This action which takes place with each movement or throw of the pushers underfeeds fresh fuel to the fire.

An important feature of this stoker is the preheated-air arch, installed directly above the coking plates. Air for the furnace is introduced into the interior of this arch where it is heated, and then passes into the furnace through tuyeres in the front of the arch.

Another McClave-Brooks stoker, designed for the burning of all kinds of anthracite coal, is known as the McClave Type M-A. It consists of a combination of the features or elements of a mechanical stoker with hand stoking and with a forced under-grate draft.

The National Stoker

This stoker is made by the M. A. Hofft Co. It is a hand stoker employing the overfeed system and can be used to burn almost any kind of fuel. Fuel is fed by hand through the furnace doors and is deposited on the upper end of the grate in a heap about 12 in. thick. The coal is left in this position to coke, until it is time to put in another charge. Before putting in a new charge the coked coal at the top is slid down onto the pushers by means of a short-handled hoe or the back of a shovel. The entire fuel bed is then worked down toward the dump plate at the rear of the furnace by means of the pushers.

In this stoker, the stationary grate bars, inclined at an angle of 30 deg., rest at their upper ends upon a lip

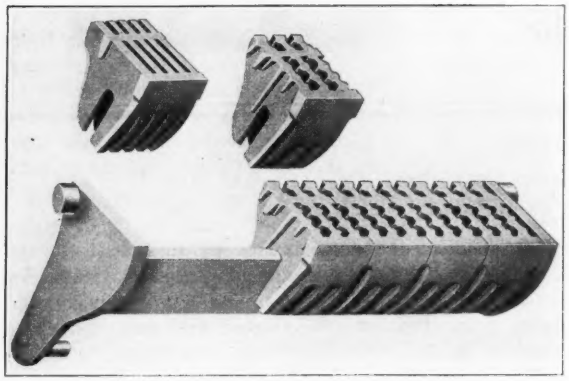


FIG. 7. CONSTRUCTION OF ROCKER BAR IN THE PERFECTION STOKER

projecting from the dead plate, while the lower ends rest upon a heavy bearing bar extending across the furnace and supported at each end on side walls. The upper ends of the stationary grate bars have herringbone openings and abut on one another forming the entire surface across the grate. In the spaces between the lower parts of the stationary bars are the pushers. The latter are sector-shaped castings, the upper and side surfaces of which are flat and have openings for the admission of air. By operated levers, the pushers can be tipped up, the up-grate end rising about 10 in. above the surface of the stationary bars, thus pushing forward the fuel resting on the pusher. At the lower end of the inclined grate are the horizontal dump plates, which when operated serve to discharge the ashes into the ash pit.

The Perfection Hand Stoker

In the Perfection hand stoker, made by the Perfection Grate and Supply Co., the grate bar elements are made in two parts, i.e., a carrying or supporting member and the top sections. The top sections constitute the bars proper, and are readily renewable. The carrying member is away from the fire at all times and is not affected by the heat of the furnace in any way. The top sections are simply placed over the carrying members and are held in place without the use of bolts, rivets or any other small parts which might burn off. A view showing the construction of these bars is shown in Fig. 7.

At the rear of the furnace is located a cleaning table, which serves to dump the ashes into the ash pit. The forward part of this table, which is exposed to the direct action of the fire, is fitted with removable sections which may be easily replaced when necessary. A diagram of the Perfection grate showing the front half of the stoker in position to advance the fuel may be seen in Fig. 8.

The Vogt Hand Stoker

In Fig. 9 is shown a stoker which is made by the Henry Vogt Machine Co., Inc. It is of the inclined, sec-

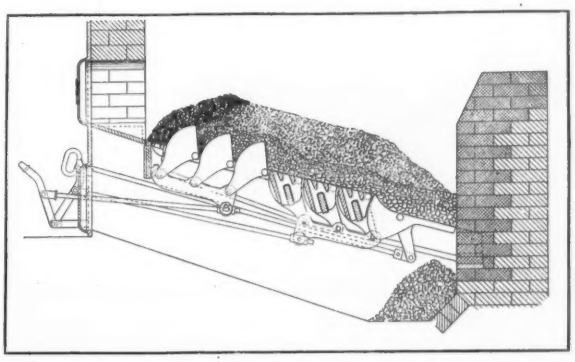


FIG. 8. SECTION THROUGH PERFECTION STOKER

tional type and employs the progressive coking method of fuel burning. The pitch of the grate surface is 18 deg. from the horizontal, this angle providing maximum combustion space without the possibility of avalanching the fuel bed. The grate surface is sectional, consisting of a series of leaves. Any leaf can be removed and replaced without pulling the fire. Since only the leaves are exposed to the intense heat of the fire, no other parts need replacement.

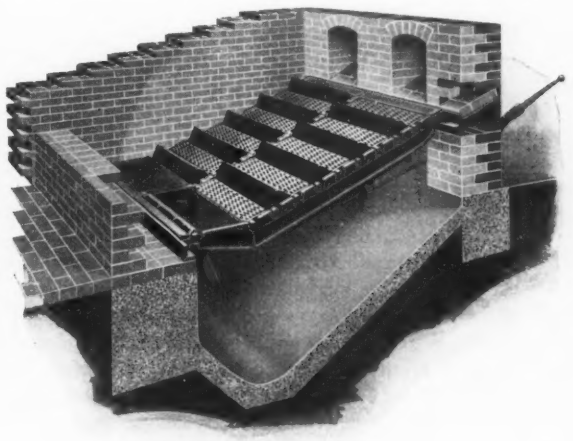
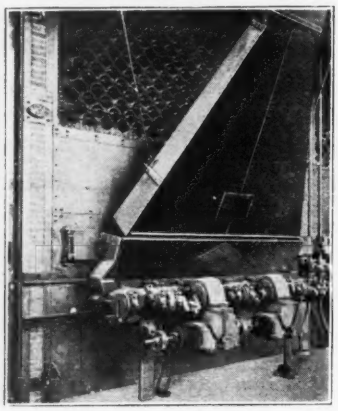
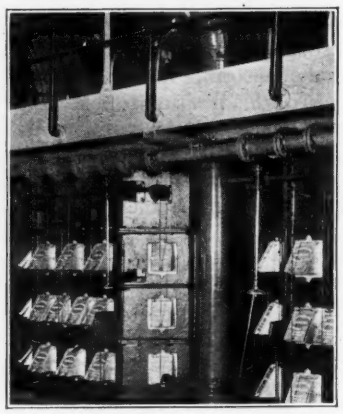


FIG. 9. THE VOGT HAND STOKER

The leaves which constitute the grate surface are supported by rocker bars trunnioned into the side frames. The leaves slip into the grooves of the rocker bar. No pins are required to lock them in place and yet they cannot be removed when in other than normal position. The effective air space is equal to 51 per cent of the grate area, and the openings are proportioned to meet the requirements of the particular grade of fuel used, and to minimize the drippings of fine coal into the ash pit.



Mechanical Stokers and Details of Furnaces For Special Fuels



UTILIZATION OF MECHANICAL STOKERS FOR BURNING COAL IN LUMP FORM AND OF SPECIAL FURNACES FOR BURNING PULVERIZED COAL, FUEL OIL, AND GAS MINIMIZES FLUCTUATIONS IN FIRING CONDITIONS AND RESULTS IN INCREASED ECONOMY

IN burning coal, the different steps follow in regular order so that the entire process lends itself to the use of mechanical stokers which conduct the coal from the hopper into the furnace, hold it intimately in contact with air during the process of combustion and discharge the ash to the ashpit when combustion has been completed. To accomplish this result, several distinct types of stokers have been developed to suit conditions of various installations, such as size of boiler served, fluctuations in load, draft available, quality of coal used and space limitations. Where coal is used as fuel, the types of completely automatic stokers in general use may be classified under one of the following heads: Inclined front-feed, side-feed, underfeed and chain grate.

These types are illustrated in the article, Mechanical Stokers for the Power Plant on page 56, under the following figure numbers: Inclined front feed, Figs. 22 and 24; side feed, Figs. 8 and 17; underfeed, Figs. 1, 5 and 9; chain grate, Figs. 3, 10 and 20.

OSCILLATING GRATES ADVANCE FUEL IN FRONT-FEED STOKERS

Inclined front-feed stokers receive coal from a hopper extending across the entire front of the furnace, the discharge from the hopper being upon an inclined coking plate from which it is pushed by oscillating plates, or slides by gravity, to a series of rocking or oscillating grate bars extending across the furnace. At the lower end of the grate are dumping plates which hold the unburned coke until combustion is completed and the ash accumulation between times of cleaning the fire. In most installations, an ignition arch is provided over the front part of the stoker which may be of either the suspended or sprung type, though the suspended type is more common.

Coal fed upon the coking plate has the heat of the furnace reflected down upon it by the ignition arch, thus driving off the volatile matter and igniting the coke. The inclination of the grates is usually around 45 deg., which is sufficient, with the aid of the grate-bar movement, to cause the fuel to descend. At the same time, the working of the grate breaks up the cakes of coke, providing air spaces through the fuel bed and sifting the ash to the space below. What reaches the dump plates is the coarser ash, clinker and some unburned coke.

These stokers are adaptable to the use of low volatile coking bituminous coals such as are found in the eastern states which require agitation of the fuel bed and are not particularly difficult to ignite. Forced draft has been used successfully with the inclined front-feed stoker; but, if the fuel bed is more than 6 in. thick, the grates will not agitate it sufficiently for good combustion. When used with natural or induced draft, these stokers are not suitable to conditions where the load fluctuates rapidly from one extreme to the other. The maximum rate of combustion is about 35 lb. of coal per hour per square foot of grate surface with draft over the fire at about 0.5 in. of water.

SIDE-FEED STOKERS GIVE RAPID IGNITION

Side-feed stokers differ little in principle of operation from the front-feed type. In this type, use is made of two inclined grate surfaces which face each other so as to form a furnace of "V" cross section, the bars running parallel with the travel of the fuel bed. Coal hoppers are placed along the full length of each side of the furnace. The furnace is always of the extended front type with an arch covering the entire space over the grates. The process of combustion is essentially the same as that in front-feed stokers, but in this case clinker grinders are usually employed to remove the ash automatically. Due to the bottling effect of the furnace, the temperature runs higher than with the front-feed type, making ignition more rapid but limiting the kinds of fuel used to those containing ash with a high temperature fusing point. Draft conditions and rate of combustion are practically the same for side-feed as for front-feed stokers.

In operation of both these overfeed types of stokers, the greatest difficulty is to adjust the hopper gate opening and the motion of the grate bars so that the proper

combustion rate is secured and no holes develop in the fuel bed. These stokers are also likely to sift considerable fine unburned coal through the grate during the early stages of combustion. With proper arrangement of the ashpit, these siftings are not lost, as they can be refired without much difficulty; but, if too much of the partly burned coal is put into the hopper at a time, furnace conditions are likely to be upset, resulting in temporary reduction in efficiency.

Smokeless Combustion Characteristic of Underfeed Stokers

Underfeed stokers are designed on the principle that the hottest part of the fuel bed should be located where its radiant heat will impinge directly upon the boiler heating surface. Coal is pushed from the hopper into a retort by means of a reciprocating plunger. The retort is somewhat similar in shape to a trough with the green coal forced in along the bottom, rising to the surface during the process of coking and ignition and overflowing at the sides or end, depending upon whether the stoker is of the horizontal or inclined type, to the dump plates or clinker grinders, if they are provided.

As the fuel bed carried on underfeed stokers is usually 24 in. or more thick, forced draft is essential for their operation, the air pressure carried ranging as high as 5 to 6 in. of water. Air is forced into the fuel bed through tuyeres along the sides of the retorts, passing through the fuel bed, and becoming heated before supplying oxygen for the combustion which is most intense at the upper surface of the fuel bed. The volatile gases driven off during the ascent of the fuel in the retort pass through this incandescent bed at the surface and due to the forced draft are thoroughly mixed with air so that combustion of the gases is complete at a comparatively short distance above the fuel bed.

Underfeed stokers are particularly well adapted for coals high in volatile constituents, which have caking characteristics and whose ash content is low and nonclinkering. The continual agitation of the fuel bed keeps it porous even with coals that cake and, where quick steaming to meet high overloads is desired, the underfeed stoker may be used to advantage. Eastern coals may be burned continuously at a rate of 60 lb. per square foot, while for short periods the combustion rate may be increased to 70 lb. With western coals, however, the combustion rate is lowered to around 35 to 40 lb. Fires on underfeed stokers are easily banked and when needed, the boilers may be brought into service in a remarkably short time.

Furnaces for underfeed stokers are not so large as others of equal coal-burning capacity, and they require no special arches to secure ignition and proper mixture of furnace gases.

Chain Grate Stokers an Early Development

Stokers of the traveling grate type were the earliest form to be developed. As early as 1819 William Brunton of England built a circular traveling grate revolving on a vertical spindle. The original chain grate, however, is credited to Jukes of England and was brought out in 1841. The earliest record of the traveling grate in America was in 1871 when Royal F. Weller built one similar to the Jukes.

In its elemental form, the chain-grate stoker consists of an endless grate composed of sections of bars passing over sprockets. The coal is fed from a hopper to the grate, is ignited by passing under an arch and is carried with the grate toward the rear of the furnace as the combustion progresses, gradually burning to ash. The ash and refuse are automatically dumped as the grate turns over the rear sprocket.

Stokers of this type have been widely used for burning the bituminous coals of the Central West which are of the non-coking type and are high in ash and volatile matter. In recent practice they have also been used to advantage with anthracite screenings and coke breeze.

Since the tars of a caking coal fuse and run at a temperature lower than that of volatilization, such coals have a tendency to clog the air passages of the grate. In chain grates using coal of this character, a coking plate is provided, upon which the coal drops from the hopper and on which it remains until the volatile matter has been driven off; the coked coal is then delivered to the grate. Other designs have been developed to handle this difficulty such as a grate bed having a weaving motion as it passes through the furnace, thus breaking up the mass of coke. In another type, a distinct drop of several inches is provided for this purpose.

Chain grate stokers are used with either natural or forced draft and are sometimes provided with draft compartments under the grate to give a zone control of combustion. At light loads this is an advantage, since it is possible to reduce the area on which the fuel is burned, thus giving a higher rate of combustion and usually higher efficiency.

One of the difficult problems in using chain grate stokers is to secure ignition, particularly with coals which are low in volatile. For this reason all chain grate stokers are provided with an ignition arch to reflect the heat from the rear down upon the fresh coal at the front of the grate.

Any leakage of air around the back end of the grate is also a source of loss, unless provision is made for heating this excess air before it reaches the furnace. This leakage may be prevented by the use of a closed ash pit with a baffle placed beneath the rear end of the stoker, a dump plate, or a water back placed on an overhung bridge wall.

One gallon of linseed oil plus 40 lb. of white lead will cover from 250 to 350 sq. ft. of outside work with a good first coat. The same quantity will second-coat and finish from 350 to 450 sq. ft. White lead when used on inside work turns blackish-yellow on account of exposure to the sulphurous fumes from gas or coal. White zinc is accordingly preferable for inside work, but, having less covering capacity, and less opacity, more coats are required.

For iron and steel work, red lead, 49 lb. per gal. of oil, is an expensive but durable covering. To prevent blistering on outside work, boiled oil should be used. Turpentine only should be used for thinning. Knots and pitchy surfaces on wood should be coated with shellac varnish, and all grease, scale, acid, and moisture should be removed from all work before painting. Graphite mixed with linseed oil and laid on in fairly thick coats makes a good paint for metals. Iron pipes, stacks, boiler fronts, etc., may be painted with asphaltum thinned with turpentine.

Drive and Speed Control of Mechanical Stokers

SPEED CONTROLLING DEVICES OF STOKERS ARE OFTEN ACTUATED BY AIR SUPPLY MECHANISM TO GIVE CORRECT PROPORTIONING OF AIR TO FUEL

IN CONSIDERING methods of drive for mechanical stokers, it will be found that most commercial forms of stokers group themselves, conveniently, into either of two classes, i. e., those which are driven by an external prime mover and those which have the driving mechanism incorporated directly in the design of the stoker. In the former type, the driving power is furnished by some commercial form of turbine, motor or engine, while in the latter type the driving device usually consists of a steam or hydraulically operated ram built integral with the stoker and which forces a certain amount of coal into the furnace at each stroke.

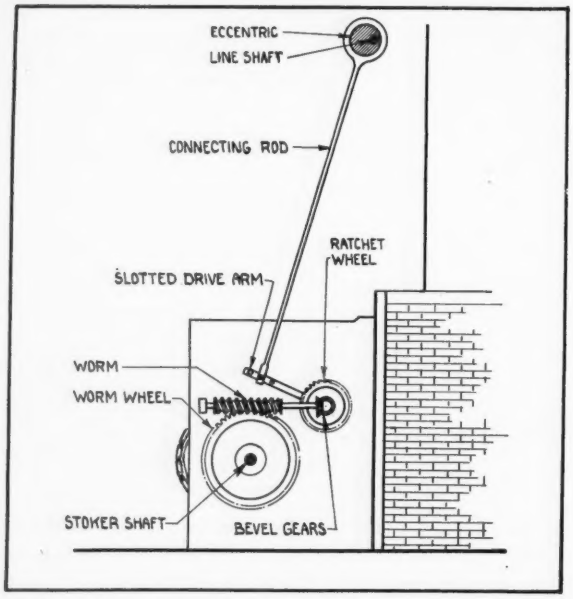


FIG. 1. COMBINATION WORM AND RATCHET ARRANGEMENT FOR CHAIN GRATE STOKER DRIVE

Since mechanical stokers are inherently slow speed devices, it is usually necessary to provide some form of speed-reducing mechanism which will allow the use of average speed motors and engines. In some cases, such reduction gear is built directly into the stoker, while in others it takes the form of an intermediate element between the driving motor and the stoker drive shaft.

To effect the necessary speed reduction, any standard form of reduction gearing may be employed, but in commercial practice the worm type of gear is much favored. This is well adapted to convert motion at high speed into extremely slow-speed motion and therefore fulfils the natural requirements of stoker drives.

Chain grate stokers are usually driven through some combination of worm and ratchet arrangement as shown in Fig. 1. In this case, power is transmitted from a line shaft through an eccentric, connecting rod, a slotted drive arm, ratchet wheel and pawl, mitre gears, worm gear and wheel to the front stoker shaft. This arrangement permits of adjustment throughout a wide range of speed by means of the slotted drive arm.

With the type of drive just described, the movement of the stoker is intermittent, due to the action of the ratchet wheel and pawl. While this can not be considered objectionable, it is at times desirable to provide a type of drive which is continuous. An arrangement of this kind is illustrated in Fig. 2. Instead of employing the mitre-gear drive, this arrangement makes use of two sets of worm gears in series. Variation of stoker speed is secured by interposing some form of standard transmission gear between the common line shaft and the stoker pulley. Where the line shaft is omitted and individual drive is used, the stoker can be connected to the driving unit, by means of either a belt or gears.

Some makes of stokers use spur gears to effect the necessary speed reduction in the driving mechanism. This type of gear has a high transmission efficiency and

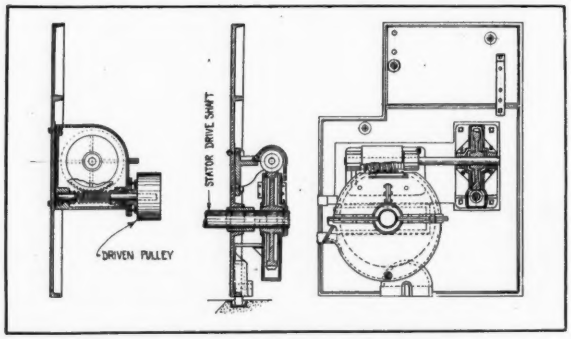


FIG. 2. DOUBLE WORM GEAR TYPE OF DRIVE

is not dependent on continuously lubricated surfaces as is the worm gear. With spur gears, the actual method of drive is similar to that used with worm gears. A typical stoker drive mechanism using spur gears is shown in Fig. 3. A pawl attached to the slotted drive arm advances the driving gear wheel a few notches with each stroke, the amount of advance being dependent upon the point of connection of the drive arm to the connecting rod. The safety spring provided on this drive is of interest. If the mechanism of the stoker becomes caught in any way, the easy tension in the spring case eliminates the possibility of breakage. The driving shaft confines its operation to the spring case until the obstruction is removed.

Other forms of gearing, however, are also used and, in the case of one well known make of stoker, a new design was recently placed upon the market, with planetary reduction gears. Aside from the fact that the planetary form of gearing permits of wide variations in transmission ratios, a higher efficiency is claimed for this gear. A view of this drive is shown in Fig. 4.

Methods of speed control for stokers depend to a large extent upon the type of stoker and upon the type of drive used. In stokers of the underfeed type a certain amount of speed variation is obtained by means of gear-shifting arrangements incorporated directly in the design of the stoker. In addition to such gear-shifting

or belt-shifting arrangements, the speed of the prime mover can, in many cases, be varied.

In the case of motor drives, however, a number of obstacles present themselves when an attempt is made to vary the speed over a wide range. The load on stokers is variable under different operating conditions, and in many cases wound-rotor motors with speed control and armature control on direct-current motors have not been entirely satisfactory.

Speed ranges for stoker motors vary from 2 to 1 to as high as 4 to 1. When wound-rotor motors or armature control on direct-current motors is used, the variations in the torque requirements, especially at the low speeds, are likely to cause the motor to stall. This condition is overcome by the use of a shunt-wound direct-current motor with shunt-field control, which makes an ideal motor for this application.

In some cases of stoker drive, the torque rises on the lower speeds. When used with a gear box, this means that the stoker speeds on any one notch of the controller with different gear speeds will not be in the same ratio as the ratio of the gears. Also the motor, still running with the same secondary resistor and with

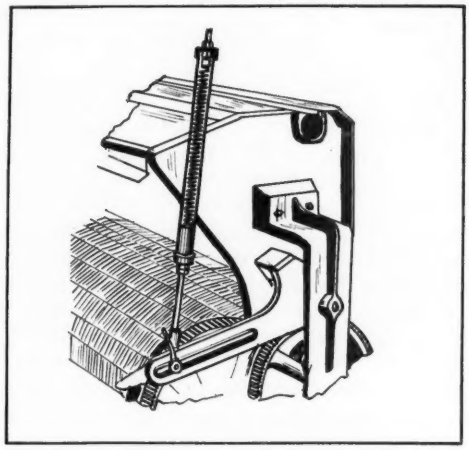


FIG. 3. THE SPRING IN THIS CONNECTING ROD PROTECTS THE STOKER FROM DAMAGE

a 2 to 1 gear ratio, has to develop, to produce the desired speed on the stoker shaft, only one-half the torque required when the stoker is running at higher speed. This also further affects the speed control that is obtainable. On account of conditions such as this, the use of wound-rotor motors on stoker drive with automatic regulators will not always be successful.

With alternating-current motors, the use of 4 to 1 speed range is usually a difficult condition to meet. The different methods of obtaining the variable speed are as follows:

(a) A constant speed motor with a mechanical speed-changing device, such as a gear box or a variable speed transmission.

(b) A wound-rotor motor with 2 to 1 speed control by resistance in the secondary and a 2 to 1 gear box giving a total of 4 to 1 speed range.

(c) A four-speed squirrel-cage motor, giving speeds corresponding to 6, 8, 12 and 16 poles, with a 2 to 1 ratio gear box giving in addition 300 to 225 r.p.m. or in all 6 fixed speeds.

(d) A two-speed wound-rotor motor, giving speeds of 1200 and 600 r.p.m. by pole changing, with speed control by secondary resistance, thus obtaining a total range of 1200 to 300 r.p.m.

Speed Control of Direct Steam-Driven Stokers

In underfeed stokers operated by direct-acting steam rams, the mechanism for obtaining speed variation usually takes the form of an automatic steam valve. The Jones underfeed stokers make use of an interesting ar-

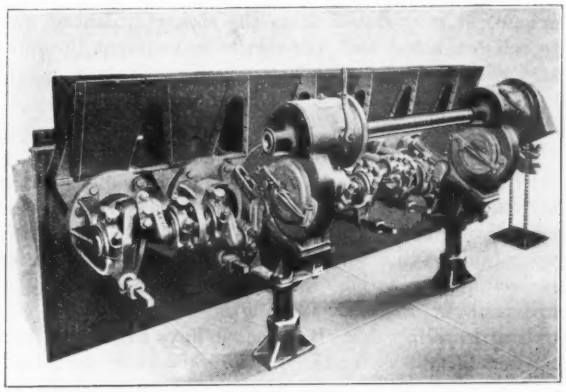


FIG. 4. STOKER DRIVEN THROUGH PLANETARY GEARS

rangement of this type, known as the Cole Automatic Valve. This usually operates in conjunction with the forced-draft blower and, when used in this manner, brings about a correct ratio of air and fuel, regardless of fluctuations in the plant load. The Cole valve is driven by belt from the blower motor or engine and

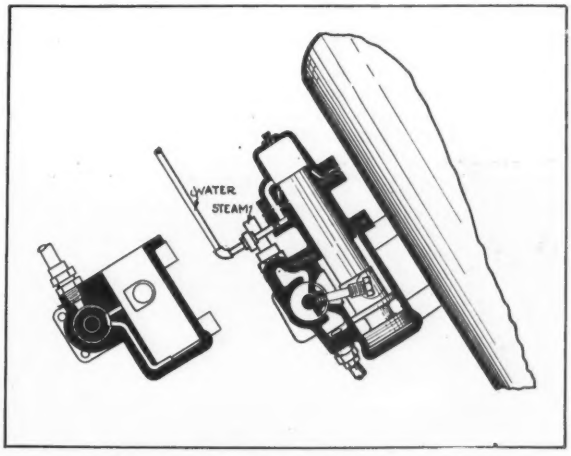


FIG. 5. CONTROL VALVE FOR TYPE E STOKER

controls the admission of steam to the steam cylinders which actuate the rams. When more than one ram is installed, the valves are arranged to operate the rams successively. The rate at which the rams are operated naturally is dependent upon the speed of rotation of the driving shaft.

In installations of this type, the blower engine or motor is usually controlled by an automatic steam-control regulator on the steam line leading to the engine. This steam regulating valve is set for the desired steam pressure. If the pressure falls slightly, this valve auto-

matically increases the speed of the engine, which in turn increases the speed of the fan and of the Cole valve; more air and coal are furnished and the rate of combustion is increased. The Cole valve has eight different rates of adjustment so that it may be set at any point by the operator to meet special fuel conditions to secure best results.

Another type of control valve for obtaining speed regulation is shown in Fig. 5. This valve which is used on the Type E stoker resembles a simplex steam pump in principle, but by its design permits of a lag between strokes. It is operated from the stoker crosshead and is a self-contained unit, capable of adjustment throughout a wide range of speed.

Correct Proportioning of Air Supply to Different Sections of the Fuel Bed Is Important

In coal-fired furnaces, combustion takes place when the fuel is allowed to unite with the oxygen of the air under favorable conditions of temperature, in such a way that rapid oxidization results. Of the two elements involved in the action, coal and air, one is exactly as important as the other. If either one is incorrectly applied, waste results. Because we have to pay out perfectly good dollars for the coal, we are likely to belittle the value of the air. Were the charge reversed, we would consider the coal in the same light.

To burn completely 1 lb. of carbon requires, theoretically, 2.66 lb. of oxygen or 11.55 lb. of air. With our present systems of burning coal, operation according to theoretical dictates is impossible. In practice, it is necessary to supply considerable quantities of excess air to insure that every particle of combustible has access to all the oxygen it can use. Good practice requires anywhere from 30 to 50 or 60 per cent excess air for coal burned on a grate. In some small plants, as much as 300 per cent excess is permitted to pass through the furnace.

Some idea of the total volume of air handled by a furnace may be had when we consider that with only 50

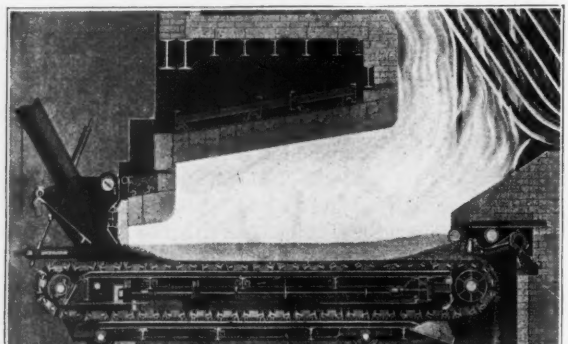


FIG. 6. UNIFORM THICKNESS OF FUEL BED IS MAINTAINED BY A FUEL RETARDER AT THE END OF THE GRATE

per cent excess there are 17.3 lb. or about 235 cu. ft. of air required for every lb. of carbon. Under these conditions, a 500-hp. boiler operating at rating with an overall efficiency of say 70 per cent, where 13,000-B.t.u. coal is used, would require almost 400,000 cu. ft. of air per hour; i.e., in an hour such a boiler would use all the air in a space measuring about 73 ft. on a side about 7 stories high.

From the point of view of economy, it is desirable to maintain a low draft over the fire, somewhere in the neighborhood of 0.05 in. of water, never more than 0.25 in. Excessive draft over the fire means considerable loss due to infiltration through the furnace setting. With positive pressure in the furnace there is a tendency for the gases of combustion to leak out. As a result, the temperature of the furnace lining is unduly increased; heat is literally driven into the walls. This over-fire draft, whatever it may be, should be kept as constant as conditions permit. Variations mean loss of efficiency.

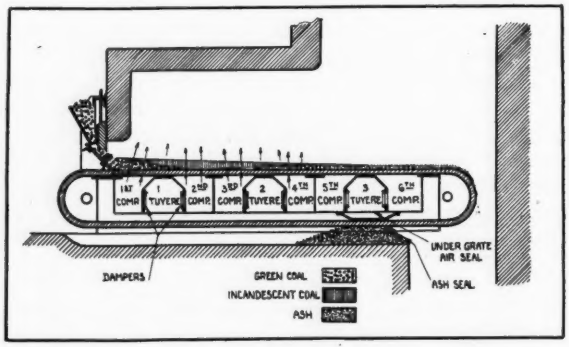


FIG. 7. RATE OF AIR FLOW THROUGH SUCCESSIVE SECTIONS OF THE GRATE IS CONTROLLED BY THE PRESSURE IN THE SEVERAL WIND BOXES

Where natural draft is employed, the pressure under the grate is, of course, constant and to obtain the necessary flow of air through the fuel bed, it is essential that the over-fire draft be relatively high. Further, as the rate of burning varies the over-fire draft will also have to vary to maintain through the grate the correct differential corresponding with the fuel consumption.

Where forced draft is employed, the windbox pressure may be so manipulated in relation to the uptake damper position or the suction fan, and both in relation to the rate of fuel consumption, as to maintain a practically constant over-fire draft. The under-grate pressure may be adjusted either by controlling the speed of the forced-draft fan or by altering the position of the wind-box dampers.

The combustion of coal takes place in several stages. First a relatively thick layer of green coal is introduced into the furnace; this is heated by radiant heat from the rest of the fire and the volatile gases are driven off; at the same time coke is being formed. Gradually this coke comes to a red heat and is consumed. As combustion progresses, the fuel bed becomes thinner and the proportion of carbon to ash is reduced until, at the end of the grate, nothing should be left but ash. During this progress, the air requirements are gradually reduced until only ash remains, when, of course, no air should be supplied. As the fuel bed thins out, however, the resistance to air flow is reduced and, unless steps are taken to prevent it, the supply will increase in inverse ratio to the requirements.

In some types of chain grate stokers, a fuel retarder is employed. This is simply a low water-back against which ash and combustible matter piles up so that the

thickness of the fuel bed is kept practically constant, as shown in Fig. 6. The inherent increase in resistance through a unit thickness of fuel as the ash percentage increases results in a gradual reduction in air flow toward the end of the grate.

Other forms of chain-grate stokers employ zone combustion. In this type of construction, the wind box under the grate is divided into a number of sections in which the pressure may be adjusted, by manipulation of dampers, to suit the requirements of the particular section or zone of the grate served. Such construction is shown in Fig. 7. The particular grate shown uses six equally spaced zones. Other arrangements may be used depending on the quality of fuel that is to be burned. For the higher volatile coals, the first zone is made to cover a greater proportion of the grate surface. This same zoning effect may be accomplished by using only one wind box and a system of dampers between cross partitions immediately under the grate for varying the flow through the various sections of the grate.

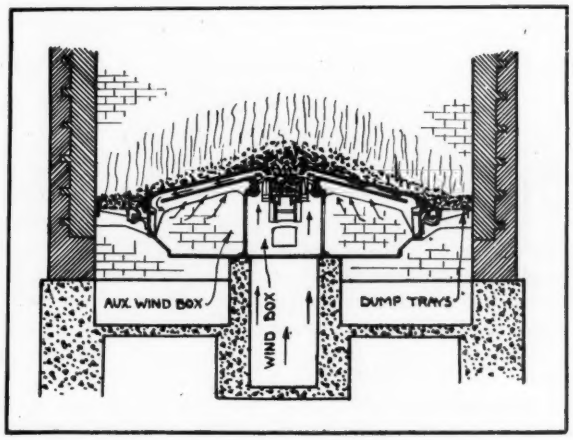


FIG. 8. AIR FOR THE SECONDARY STAGES OF COMBUSTION IS PREHEATED BY ITS PASSAGE THROUGH HOLLOW GRATE BARS

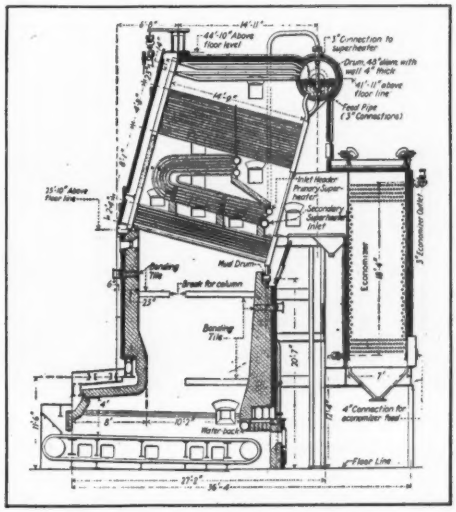
Arrangements for supplying air to underfeed stokers are relatively simple for the reason that the combustion over a given section of the grate is nearly uniform; the progress of combustion is in a vertical rather than in a horizontal direction. In a typical underfeed stoker air is supplied from one wind box, which is of rather ample proportion, for the purpose of converting the velocity energy of the entering air into pressure energy. Air passes upward on either side of the retort to about the point where the coal beings to glow; here part of it enters the fuel bed and part is deflected through hollow grate bars to auxiliary air boxes, thence through openings between the fire bars to the coking fuel bed, as shown in Fig. 8.

Another type of underfeed stoker arrangement is shown in Fig. 13, page 59, where air is supplied to the coal in the first stages of combustion through small horizontal openings between the underfeed reciprocating grate block. As combustion progressse, the upper surface of the fuel bed slides down the inclined surface to the overfeed section. The air requirements here are diminished and the supply to this section is controlled by a damper admitting air from the main wind box.

1200-Lb. Boilers a 1923 Development

ONE OF the interesting developments of 1923 was the 1200-lb. boiler which was announced by the Babcock & Wilcox Co. in June. Although boilers of this pressure are in the experimental stage, several installations are under way, which will test them out on an operating basis. At the new Weymouth station of the Boston Edison Co. and at the Calumet station of the Commonwealth Edison Co., Chicago, these boilers are now being installed.

In each case they will be operated on a reheating cycle. Steam will be furnished at 1200 lb. to a high-pressure turbine. The exhaust from this machine at 300 or 375 lb. will be taken back to the boiler and reheated in a superheater, to the initial steam temperature. At this temperature the steam will pass into the regular station steam headers for use as may be desired.



1200-LB. BOILER WILL BE INSTALLED FOR A COMPOUND REHEATING CYCLE

As shown in the accompanying sectional view, the unit is of the inclined header, cross-drum type and comprises: A Babcock & Wilcox forced-draft chain-grate stoker 24 ft. wide and 18 ft. 3 in. long; a lower deck of eight-high sections of 2-in. tubes having a setting height of 25 ft. 9¾ in.; a primary and a secondary superheater in an interdeck space 8 ft. 1¼ in. between decks; an upper deck of seventeen-high sections of 2-in. tubes; two rows of horizontal 3¼-in. circulating tubes entering a 48-in. cross drum; and a Babcock & Wilcox steel contraflow economizer. The lower deck is not baffled; the upper deck has a vertical baffle causing the gases to make two passes. The complete unit is about 28 ft. wide, 36½ ft. deep, including the economizer, and 45 ft. high above the floor. The heating surfaces have not yet been definitely fixed, but they will be approximately as follows: Boiler, 15,750 sq. ft.; primary superheater, 2120 sq. ft.; secondary superheater, 3300 sq. ft.; economizer, 9230 sq. ft.

One marked point of difference in the construction of this boiler is in the cross drum. This drum is a forged steel cylinder, 48-in. diameter with 4-in. walls made up by rolling on a mandrel and swaging the ends.

Mechanical Stokers for the Power Plant

APPLIED COMBUSTION ENGINEERING OWES MUCH OF ITS PRESENT HIGH STANDARD TO THE DEVELOPMENT OF THE MECHANICAL STOKER

STEAM MAKING is a factory problem in which water and fuel are the raw materials and steam the product. Each operation in the process of steam making repeats itself day after day and the recurrent losses or gains will inevitably show on the ledger at the end of the year. It was high steam costs which caused American industry to seek more efficient methods of fuel burning. This demand has brought about large boiler units which cannot be fired economically by hand, and it has brought high ratings which can only be obtained, in coal-fired furnaces, by the use of mechanical stokers. Economic pressure has forced the stoker issue because it is a logical solution for burning cheap and low grade fuels which were at one time considered unfit for power purposes.

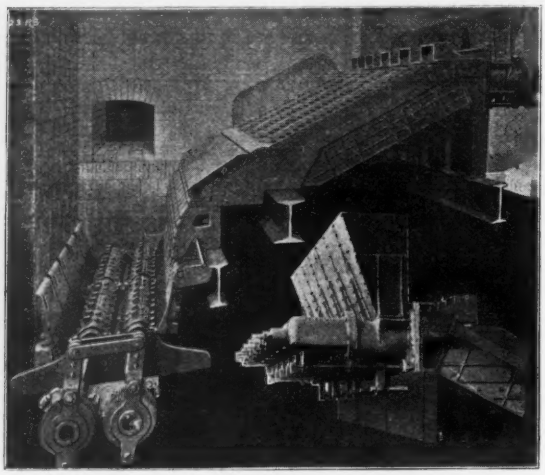


FIG. 1. TAYLOR MULTIPLE RETORT UNDERFEED STOKER. INSERT SHOWS STOKER EQUIPPED FOR HYDRAULIC DRIVE

In the following descriptions will be found stoker types which will meet the requirements of present day steam production.

AMERICAN ENGINEERING COMPANY

Taylor stokers, as illustrated in Fig. 1, with either hydraulic or crank-shaft drive are built by the American Engineering Co. In the former type, each retort ram is driven by an individual hydraulic cylinder connected to a high pressure, variable and reversible delivery hydraulic pump also made by the American Engineering Co. This arrangement is flexible and eliminates the possibility of breakage due to foreign matter in the coal.

In both the hydraulic and crank-shaft drive stokers control of the fuel is afforded throughout the furnace by a series of interlocking flat distributing rams which form the bottom of each retort. The main feeding ram drives the front ram of the series which in turn drives the one next to it and in this manner the stroke is transmitted by one ram to the next from front to rear of the stoker. The relative stroke of the individual rams in the series can be adjusted. This gives a feed of fuel graduated throughout the retort, to meet the burning characteristics of the fuel being used.

On the crank-shaft type stoker, positive protection is provided for the driving mechanism from foreign matter fed in with the fuel by equipping each feeding ram with an unloading toggle which resets itself on the outward stroke. This eliminates the need for a shearing pin. To burn out any carbon remaining in the ash a reciprocating extension grate is provided, at the end of the tuyere section, to which air is admitted under low pressure. The drive consists entirely of spur gears. Ash disposal is accomplished either by a steam operated, single-leaf dump plate or by the Taylor rotary ash discharge. The steam dump plate is arranged to swing above the horizontal to clean the bridge wall of clinker.

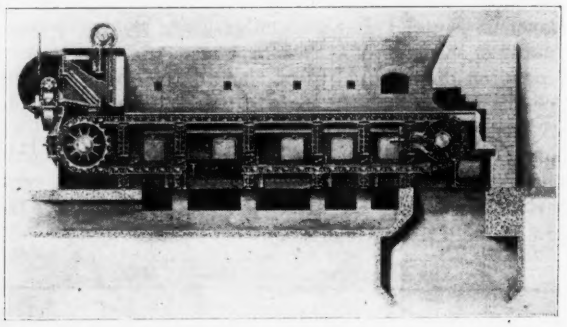


FIG. 2. SIDE VIEW OF THE BABCOCK & WILCOX CO. FORCED DRAFT CHAIN GRATE STOKER

THE BABCOCK & WILCOX COMPANY

Natural and forced-draft chain grate stokers, made by The Babcock & Wilcox Co., differ essentially only in the application to the latter of forced blast boxes and supports, and compartment dampers. In the forced-blast stoker, Fig. 2, side wall blast boxes connect with five crosswise compartments for distributing air to the grate. Each compartment is equipped with an individual damper and access door. A damper-operating rig controls opposite dampers of each compartment so that air is admitted to each end of the compartment. Driving sprockets, spaced on 13½-in. centers, are keyed to the front or driving shaft and adjustment is made to the rear shaft to which a sectional cast-iron drum is keyed. The chain or grate has four rows of wrought-steel, drop-forged driving links; the remainder of the driving links and the common links are cast iron. The top run of

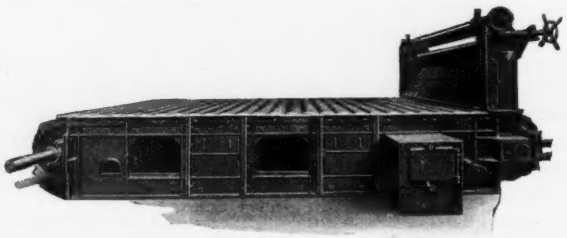


FIG. 3. COXE STOKERS ARE USUALLY DRIVEN THROUGH THE REAR SHAFT

chain slides on skids and the return or bottom run slides on ⅜-in. plates which form the bottom seal. Two sets of worm and worm wheel drives are provided so that, with a direct-current motor, chain speeds of from 2 to 12 in. per min. may be obtained.

Combustion Engineering Corporation

Coxe stokers, Fig. 3, manufactured by the Combustion Engineering Corporation, are of the forced draft type in which air is supplied to tuyeres which extend across the furnace below the active or upper grate run. The tuyeres are made of steel sheets having in the vertical sides, grid valves and frames through which the air passes to an air compartment on either side. Each tuyere with its air compartments is a unit. The number of units placed under a stoker will depend upon the length of the active fuel bed. Usually the Coxe stoker is driven through the rear shaft and the take-up adjustment is provided on the front or idler shaft. The grate surface consists of a number of narrow castings which are strung on malleable iron dovetails bolted, in turn, to carrier bars. These bars extend the full width of the stoker and terminate, on the under side in solid ends where

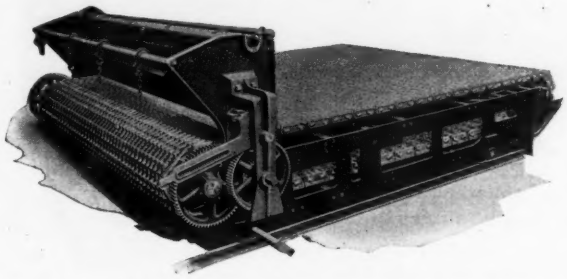


FIG. 4. BOTH CHAIN COURSES OF THE GREEN CHAIN GRATE STOKER SLIDE ON SKIDS

steel bar lugs engage drop-forged chains which convey the bars around.

Green natural draft chain grate stokers, shown in Fig. 4, also made by the Combustion Engineering Corporation, are provided with a double drive for all stokers over 7 ft. 6 in. wide. The chain construction of this stoker makes use of oval bars with solid drive links and open filler links. The open links are dropped over the oval bars when they are in the vertical position and the bar is then turned through a slight angle and held in place by the outer binder links. Quick link replacement can be made while the chain turns over the sprockets at the stoker front. Chain tension is taken up from the front end of the stoker. Both the upper and lower chain courses slide on longitudinal skids. A safety spring in the drive mechanism eliminates the possibility of breakage should the stoker become caught.

Frederick multiple retort stokers, illustrated by Fig. 5, are built by the Combustion Engineering Corporation. The main rams, spaced on 21-in. centers, are driven through crank shafts and two-speed gear boxes. The secondary rams are composed of tuyeres thus forming an addition to the active fuel burning surface. There is no long overfeed section to this stoker, for the underfeed section, sloping at 20 deg., extends practically to the air cooled dump grates. This construction results in a greater active fuel bed area. A row of non-clinkering furnace blocks is installed as part of the stoker above the retort caps. Single roll clinker grinders may be used with this stoker which is built in both central and super-station types.

Type E stokers, Fig. 6, manufactured by the Combustion Engineering Corporation, are of the single retort type with dump plates at the stoker sides. For very wide settings, a series of these stokers may be set across the furnace width. Coal is fed from the stoker hopper by a mechanically-operated retort bottom which

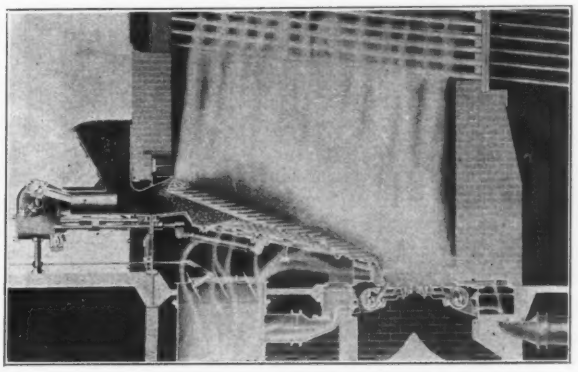


FIG. 5. SHORT OVERFEED SECTION RESULTS IN GREATER ACTIVE FUEL BED AREA ON THE FREDERICK STOKER

extends the full length of the stoker. Coal is delivered uniformly from front to rear by the auxiliary pushers and, as it rises in the retort, is distributed to the grate sides by fire bars which are arranged in pairs, alternately moving and fixed. Movement of the fire bars not only carries the burning fuel to the sides but also conveys the ash down and onto the dump plates which are operated by a ratchet lever. Air under pressure enters the wind

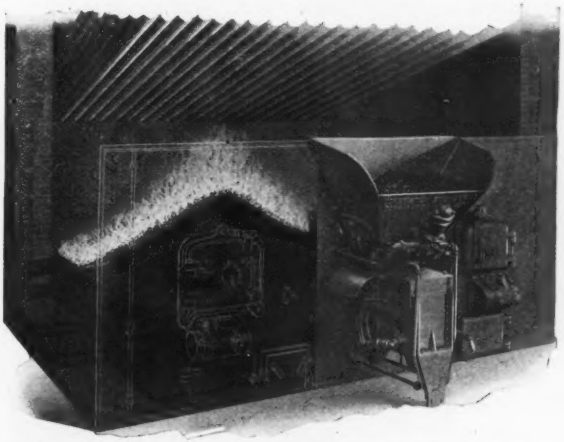


FIG. 6. AIR MAY BE ADMITTED UNDER THE DUMP PLATES OF THE TYPE E STOKER

box below the stoker and is discharged partly through the tuyere openings in the inside or retort end of the fire bars; the remaining air passes through the hollow fire bars into the auxiliary air box whence it enters the fire through openings between the fire bars. Air may be admitted under the dump grates, if required.

For boilers under 200 hp., the Combustion Engineering Corporation builds the type K stoker, as illustrated by Fig. 7. It consists of a center retort through which

the coal is fed from front to rear by auxiliary pushers as in the type E stoker. In the type K stoker the burning fuel is forced over the tuyeres, through which forced blast is supplied, thereby completing the coking operation. The incandescent coke is flooded to the side grates which are stationary or shaking, as desired.

Detroit Stoker Co.

Two types of stokers are built by the Detroit Stoker Co., these are the natural draft "V" type, Fig. 8, and

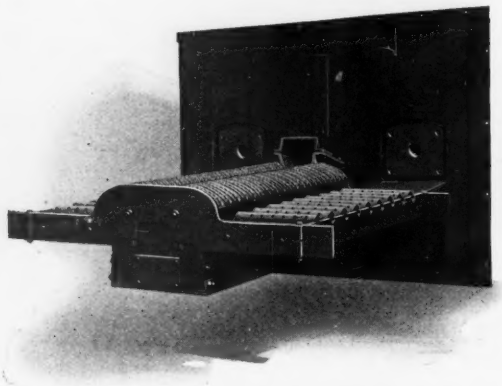


FIG. 7. TYPE K STOKERS ARE MADE FOR BOILERS OF LESS THAN 200 HP. RATING

the underfeed type, shown by Fig. 9. In the former, coal is stored in side hoppers from which it feeds by gravity to the sloping grates. The fuel bed moves downward towards the center of the furnace where the ash and clinker are discharged through the clinker grinder which is mechanically operated as are the vibrating grates. The arch over the furnace may be either of the suspended type or of the air-cooled sprung type.

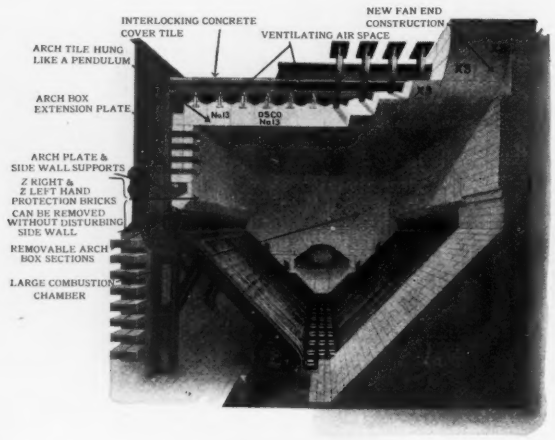

INTERLOCKING CONCRETE COVER TILE
NEW FAN END CONSTRUCTION
VENTILATING AIR SPACE
ARCH TILE HUNG LIKE A PENDULUM
ARCH BOX EXTENSION PLATE
ARCH PLATE & SIDE WALL SUPPORTS
Z RIGHT & Z LEFT HAND PROTECTION BRICKS CAN BE REMOVED WITHOUT DISTURBING SIDE WALL
REMOVABLE ARCH BOX SECTIONS
LARGE COMBUSTION CHAMBER

FIG. 8. COAL FEEDS BY GRAVITY FROM SIDE HOPPERS ON THE TYPE "V" STOKER

Detroit underfeed stokers are built with single or multiple retorts. The former are side cleaning, regulation of coal feed and clinker and ash removal being accomplished without interference with the stoker operation. The grate surface of the Detroit underfeed stoker is horizontal. Fuel is fed from the stoker hopper to each retort by a plunger which is power driven by a crank shaft, forward movement of the fuel bed being accomplished by a power pusher bar in each retort. Ash is worked to the back end of the stoker to a balanced hand or power operated dump plate. The crank shaft is driven through two worm gear reduction units which are carried on roller bearings in an oil bath.

Illinois Stoker Company

Natural and forced draft chain grate stokers, built by the Illinois Stoker Co., are of the link chain type with take-up and drive located at the front. Drive sprockets engage on loose rollers mounted on twisted steel chain rods and at the rear the chain passes over an idler drum. Both the upper and lower chains travel on chain skid bars, as shown in Fig. 10. On the natural draft stokers, patented air control dampers are provided, which permit air control to suit various fuel bed conditions at any portion of the grate. Damper-operating rods do not interfere with pulling out the stoker which is mounted on rails. Baffles are arranged to prevent air entering the combustion chamber except through

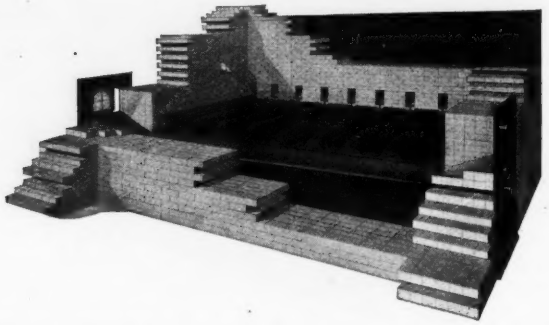


FIG. 9. DETROIT UNDERFEED STOKERS ARE BUILT WITH SINGLE OR MULTIPLE RETORTS

the grate. The entire active grate length of the forced draft stoker is divided into a number of zones which are controlled by individual dampers.

Laclede-Christy Clay Products Company

Design of the Stowe stoker is shown by Fig. 11. This stoker, built by the Laclede-Christy Clay Products Company, employs the conveyor feed principle and is designed for the use of mechanical draft. Its design consists chiefly of stationary tuyeres, alternating with moving chains, and a fuel retarding assembly at the ash discharge end. These units combine to effect a closely massed fuel bed of uniform thickness under which full wind box pressure is used. The conveying influence is made positive through the moving chains and sharp incline of the grate. The grate surface is composed of about 60 per cent moving and 40 per cent stationary elements.

Stationary tuyeres, together with the rear housing, provide the retarding influence which maintains a thick and closely massed fire to the end of the grate. The problem of air leakage is solved by actually housing the ends of the fuel conveying mechanism, leaving unhoused only that portion of the grate actually supporting the fuel bed.

Chain grate natural draft stokers made by the Laclede-Christy Clay Products Company are as illustrated in Fig. 12. The girder-like construction coupled

with internal bracing insures a unit in alinement at all times. The drive mechanism is of the simple worm and gear type with a change-speed ratchet device. The front or drive shaft is fitted with sprockets which engage rollers placed between the chain links. The idler shaft is fixed, the idlers revolving upon it.

Interchangeable chain links are fitted close together with air passage provided by slots in the sides of the

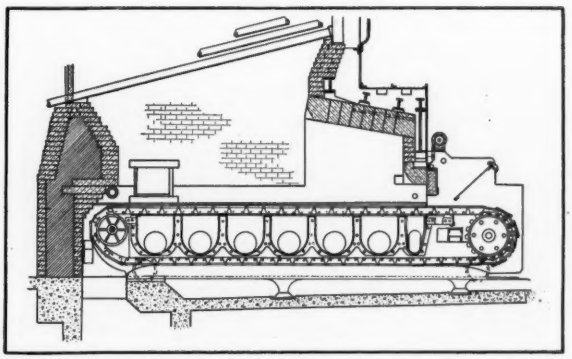


FIG. 10. ILLINOIS CHAIN GRATE STOKERS ARE BUILT WITH THE DRIVE AND TAKE UP LOCATED AT THE FRONT END

links. The chain rods are free to revolve, thus minimizing wear. Chain tension adjustment is made from the front end. Air seals are provided at the bridge wall and between the side walls and frame.

Grate surface is built on a slight incline toward the rear, thus permitting easy withdrawal and replacement of the entire stoker, a slight increase in the grate surface, and removing the grate surface farther from the boiler tubes at the rear end. Ledge plates are eliminated by the use of special tile built in the side wall. A

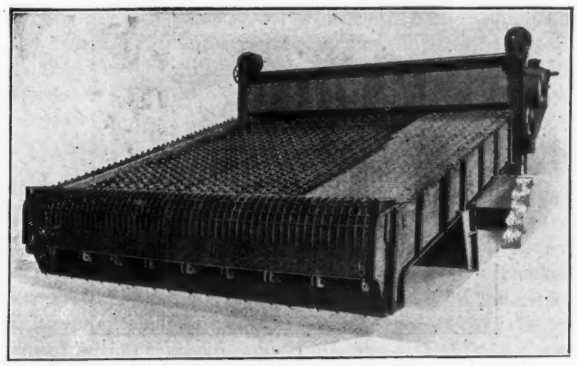


FIG. 11. STOWE STOKERS EMPLOY THE CONVEYOR FEED PRINCIPLE

swinging damper placed between the upper and lower chain runs reduces the effective grate surface on light loads and during banking periods.

Sanford Riley Stoker Co.

Stokers as manufactured by the Sanford Riley Stoker Co. are the Riley, the Jones and the Murphy. Riley underfeed stokers, shown in Fig. 13, are built in the following types: standard, intermediate, extra long and super, these vary in length from 9 ft. 2 in. to 20 ft. The first three types of Riley underfeed stokers are fundamentally the same in design; they are equipped with reciprocating retort sides or conveyor tuyeres, the rocker dump which provides continuous ash discharge, safety shearing pins, two-speed gear box and moving high side-wall tuyeres which protect the side wall and prevent clinker. Coal is fed from the stoker hopper to each retort by a plunger actuated by a power-driven crank. The extension of the plunger wristpin drives

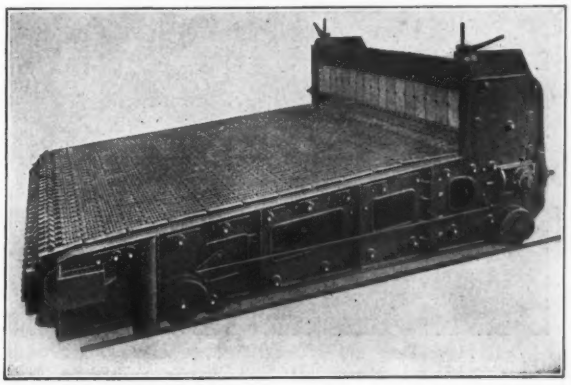


FIG. 12. CHAIN RODS ARE FREE TO REVOLVE IN THE LACLEDE-CHRISTY CLAY PRODUCTS CO.'S CHAIN GRATE STOKER

the support bar which in turn controls the movement of its corresponding retort side bar. Take-up of the lost motion between the wristpin, which always travels full stroke, and the side bar will change the travel of the retort side bar. Coke is burned out on overfeed reciprocating tuyeres located just in front of the rocker dump. Air pressure at this point is separately controlled from that under the retorts.

Riley super stokers are single ended and were designed to take the place of the double ended type. They

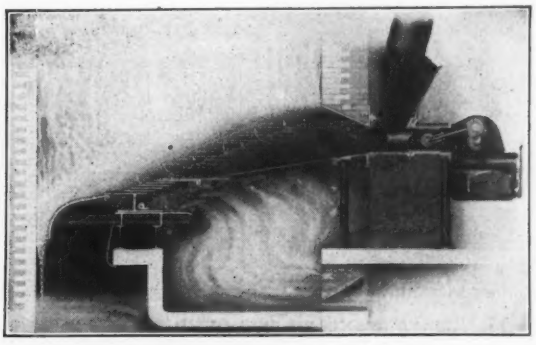


FIG. 13. RILEY UNDERFEED STOKERS ARE BUILT WITH RECIPROCATING RETORT SIDES

are built heavier than the other types although all features of the standard stoker have been incorporated in them. Two air zones are provided in the underfeed section.

Lateral retort stokers, Fig. 14, are the latest development of the Sanford Riley Stoker Co. and are for boilers of 150 to 500 hp. They consist essentially of two multiple retort units placed back to back in such a way that there is one main retort extending from the furnace front wall to the bridge wall with lateral retorts branching off at right angles. A steam cylinder actuates the

fuel-feeding ram. Coal from the main retort is forced into each lateral retort by lateral pusher blocks operated by an auxiliary steam cylinder. The length and timing of the stroke of the lateral pusher blocks may be varied independently of the main cylinder. Forced draft is supplied under the side dump plates if required.

Jones stokers as manufactured by the Sanford Riley Stoker Co. are designated as: the standard, the standard

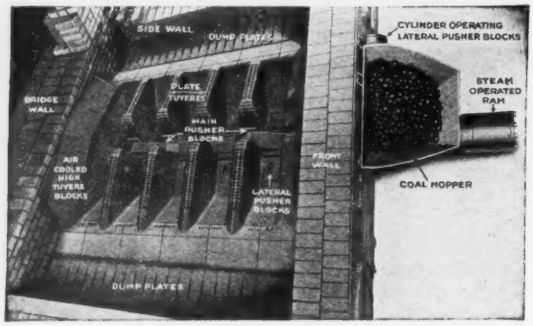


FIG. 14. LATERAL RETORT STOKER BUILT BY THE SANFORD RILEY STOKER CO. TOP VIEW

side dump, the lateral retort and the multiple retort underfeed. The standard Jones stoker is of the single retort type with plunger feed and hand-cleaned dead plates. The standard side dump stoker, Fig. 15, has the general features of the standard stoker and, in addition, it is equipped with sloping combustion grates and hand-operated side dump plates. In both of these types, coal is fed into a single retort by a power cylinder actuated pusher rod.

Jones "A-C" multiple retort stokers, shown in Fig. 16, consist of a series of unit retorts placed side by side

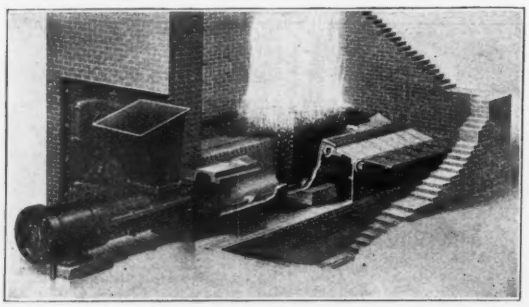


FIG. 15. JONES STANDARD SIDE DUMP STOKER IS OF THE SINGLE RETORT TYPE

across the furnace width. Each retort is equipped with a separate steam-cylinder-operated feed bar while a hand-operated dump plate extends across the rear end of the stoker. Air-cooled side tuyeres are provided to prevent clinker adhesion.

Sanford Riley Stoker Co. also manufactures the Murphy stoker, illustrated by Fig. 17, which is of the side overfeed type. At either side of the furnace, extending from front to rear, is a coal magazine or hopper at the bottom of which are the stoker boxes, resting upon the coking plates. The stoker boxes are operated by segment gears and racks moving forward and back upon the coking plate, pushing the coal through the throat opening onto the sloping grates. The coking plate is cooled by air passing under it to the rear end of the arch chamber. The grates are in pairs, one fixed and one movable, the latter being pivoted at their upper ends and moved by a rocker bar at their lower ends. The clinker grinder is actuated by a reciprocating bar which also controls the fuel feed and the grate bar movement.

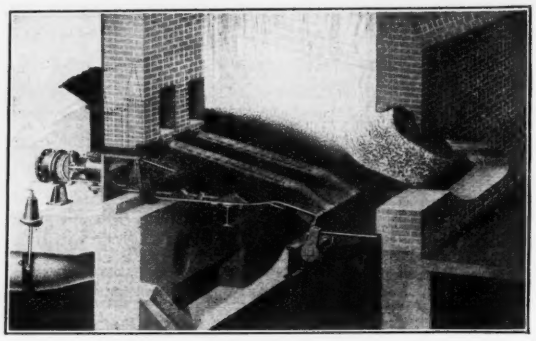


FIG. 16. JONES "A-C" MULTIPLE RETORT STOKERS ARE EQUIPPED WITH AIR-COOLED SIDE TUYERES

B. F. Sturtevant Co.

B. F. Sturtevant Co. builds two types of stokers known as the type "T" and the type "S." The type "T" stoker, Fig. 18, consists of a centrally-located horizontal retort extending lengthwise of the furnace and provided at its upper edges with tuyeres through which air is introduced to the fuel. Fuel is fed to the retort by a power-driven ram and is distributed through the length of the retort by reciprocating pushers. From the retort the fuel is fed over the entire furnace area by

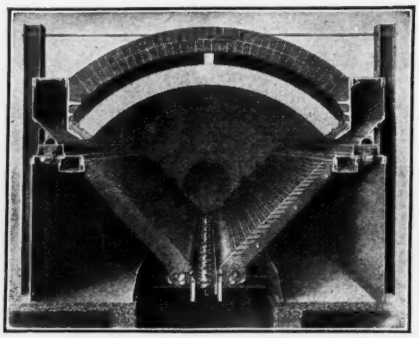


FIG. 17. MURPHY STOKERS ARE OF THE SIDE OVERFEED TYPE

means of lateral reciprocating grates. The coal ram operates within a cast-iron cylinder the face of which supports the shaft and the driving gear box. Operation of the moving parts of the stoker is obtained directly from a crank shaft at the front. The ram is connected to the crank by an automatic connecting rod designed to release the strain on the stoker during the forward motion of the ram, should it be blocked by any foreign substance in the fuel, and to restore itself to normal on the return stroke. The grates are actuated from the crank through a connecting link and lever to shafts passing under the lateral grates. These grate shafts

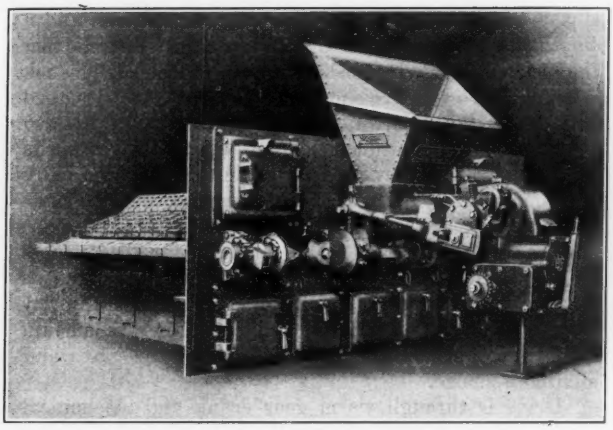


FIG. 18. B. F. STURTEVANT CO.'S TYPE T STOKER IS EQUIPPED WITH LATERAL RECIPROCATING GRATES

convey a reciprocating motion to the grates by means of racks and gears.

Sturtevant type "S" stokers, shown in Fig. 19, have a power-driven ram which forces fuel into a centrally-located horizontal retort extending lengthwise of the furnace. Air-supplying tuyeres are located at the upper edge of the retort, and shaking grates are provided between the tuyeres and the side walls. The crank shaft and reduction gears are mounted on the front of the ram cylinder which is supported from the stoker frame. The releasing connecting rod, the gear box and reduction gears are of the same general design as used on the larger "T" type stoker. Retorts are of sectional construction and are made up of a number of standard units depending upon the size of the stoker. They are of rectangular section and are provided with a slot in the bottom within which a pusher rod operates. The arrangement is such that adjustment may be made at the front for changing the position of the rod relative to the plunger or for introducing lost motion. The pusher blocks may be moved on the rod, if it is necessary to change the coal distribution. All adjustments may be made without taking the stoker out of service.

The United Machine & Mfg. Co.

Grate surface of the Harrington stoker manufactured by The United Machine & Mfg. Co. and shown in Fig. 20 is made up of individual grate clips with interlocking edges which reduce sifting to a minimum. Each clip is independently carried on racks so that it may be removed without interference while the stoker is in operation. Automatic separation of the clips as they round the stoker ends maintains the air passages free from clinker. Clip racks are secured to driving chains which take all mechanical stress and wear. The grate surface is divided into four or more air compartments which are controlled from the front of the stoker. This stoker is driven from the front by means of a direct connected motor or steam engine. All moving parts of the stoker come to the front at each revolution of the grate surface. Roller bearings on the driving chains roll on a rear girder thus eliminating a rear shaft.

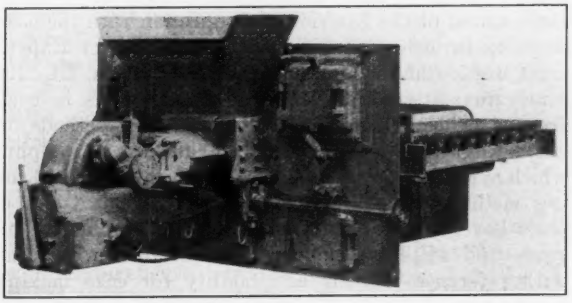


FIG. 19. STURTEVANT TYPE S STOKERS ARE PROVIDED WITH SHAKING GRATES BETWEEN THE TUYERES AND SIDE WALLS

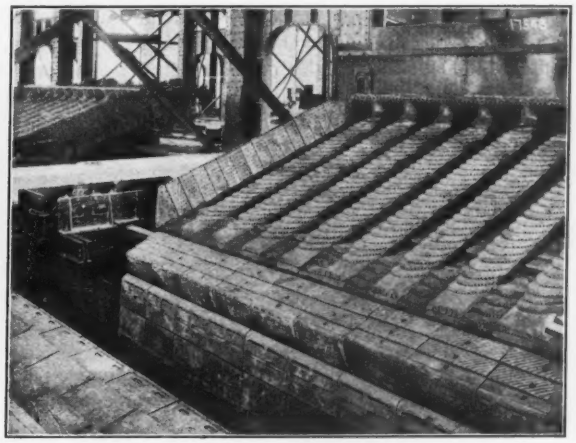


FIG. 21. RAMS DRIVE PARALLEL TO THE INCLINED RETORTS IN THE WESTINGHOUSE UNDERFEED STOKERS

Westinghouse Electric & Mfg. Co.

Westinghouse new model multiple retort underfeed stokers, shown in Fig. 21, are of the crank-drive multi-retort type in which the rams drive parallel to the inclined retorts. Secondary rams, operating counter to the main rams, feed the fuel upward and forward. Adjustment of ram travel may be made at any time and in any position of the main rams. At the lower end of the retort section is a steam or air-cylinder-driven agitating grate. Tuyeres are interlocking and so designed as to give uniform air distribution. Cast-iron extension side-wall tuyeres are air cooled and thus minimize the tendency for ash adhesion to the side wall. Both main and division dampers are provided in the wind box beneath the stoker. Ash may be removed either through power-operated double-dump grates, which are air cooled, or by single or double roll clinker grinder.

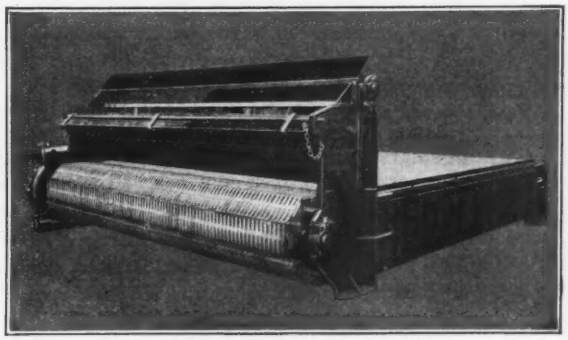


FIG. 20. HARRINGTON STOKERS ARE MADE WITH GRATE CLIPS WITH INTERLOCKING EDGES

Westinghouse-Roney stokers, Fig. 22, are of the overfeed type. Coal, fed from the stoker hopper by a pusher plate which is mechanically operated, first passes over a dead plate which is given the same general slope angle as the grate proper. Keyed to the main operating shaft is an

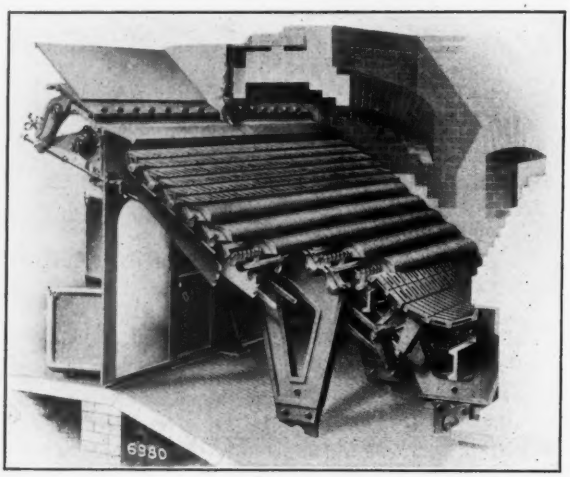


FIG. 22. WESTINGHOUSE-RONEY STOKERS ARE OF THE OVERFEED TYPE

eccentric which imparts a pendulum motion to the agitator lever, the lower end of which actuates the connecting rods by means of which the grates are rocked. The travel of the agitator lever and the pusher plate may be varied at the will of the operator. The grate bars are machine moulded and are spaced regularly in notches in a rib at the top of a strut on which they rest. In the new design there is a hand-operated auxiliary dump or guard which acts as a clinker breaker and barrier to prevent fuel from sliding into the ash pit. The main

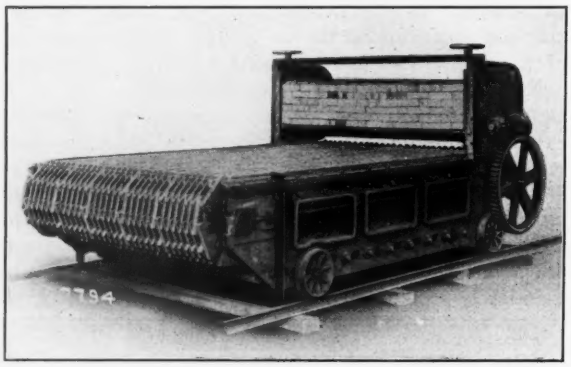


FIG. 23. VIEW OF THE WESTINGHOUSE CHAIN GRATE STOKER

dump grate moves upward and forward breaking up clinker which has bridged over or which had adhered to the bridge wall.

Natural draft chain grate stokers are also manufactured by the Westinghouse Electric & Mfg. Co. They are illustrated in Fig. 23.

McClave-Brooks Company

McClave-Brooks Company manufactures a stoker which is designated as the underfeed-overfeed type of stoker. It consists of large capacity coal hoppers and a sloping stoker grate bed upon which coal is fed from the stoker hoppers by pushers which underfeed the fuel. Alternate crosswise sections of the grate are designed with heavy journals which rotate in the carrier bars so that they kick up and feed the fuel progressively towards the ash cut-out bars at the rear of the furnace. Specially designed preheated air arch supports and tuyeres, made of cast iron, are attached to the upper front of the stokers. Air is distributed to this arch for the purpose of air cooling and is then distributed through the arch tuyeres into the coking zone of the furnace directly over the fuel. This method supplies the extra amount of oxygen necessary to drive off the volatile gases and eliminate smoke.

Drive is through worm gear crank and mechanical timer, which varies the time interval between the strokes of the pushers rather than the length of stroke. Adjustments to care for uneven fuel bed conditions may be readily made from the stoker front by setting the kicker

FIG. 24. MECHANICAL STOKER AS MANUFACTURED BY THE MC CLAVE BROOKS CO.

bars by means of a differential attachment so that they will kick and agitate the fuel at any stroke from a minimum to a maximum throw of the kickers.

In case of an accident to the driving mechanism, a simple clutch is released and the stoker load can be carried by means of hand operation, thus assuring continuous operation.

INVESTIGATIVE WORK on the amount and character of the different sulphur compounds occurring in various coals is being continued by Thomas Fraser, assistant mining engineer, and H. F. Yancey, assistant chemist, Department of the Interior, in connection with the coal-cleaning investigations at the Central District Experiment Station of the Bureau of Mines, Urbana, Ill. Recently the distribution of sulphur compounds in coals from a number of fields has been studied. Methods for estimating in a general way the amount of sulphur which may be removed from a coal by gravity coal cleaning methods have been developed. Various types of coals have been classified on a basis of sulphur occurrence and sulphur removal. The evaluation of coals with reference to their adaptability for coke making, insofar as sulphur is concerned, is thus made possible. A report on the results of the investigations is in course of preparation.

Furnace Design Important in Burning Oil

Furnace Volume and Amount of Combustion Air Are Important Factors. Types of Oil Burners

IN DESIGNING a furnace for oil burning or in changing a furnace from coal to oil firing, a number of factors must be considered. Naturally, the first point is the type of the boiler as affecting the shape of the furnace, the number of burners and the shape of the flame.

With short settings it is sometimes advisable to install dutch ovens to insure complete combustion of the oil before it reaches the boiler surface, as in the case of vertical boiler settings.

Volume of Furnace

One of the next points to consider in designing the oil burning furnace is the furnace volume as affecting the rate of combustion desired. Furnaces should be designed to permit the slowest velocity of gases consistent

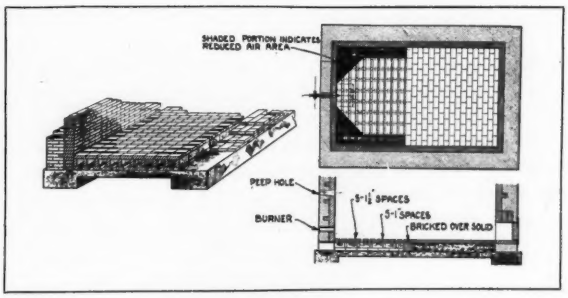


FIG. 1. METHOD OF INTRODUCING COMBUSTION AIR THROUGH FURNACE FLOOR

with the rating required. As a basis of valuation, it is usually desirable to have, as nearly as possible, one cubic foot of combustion space per pound of oil burned per hour, or, in other words, 2 to 2½ cu. ft, of combustion space per rated boiler horsepower. This figure applies to boilers where the furnace draft available is less than 0.1 in. and the resultant velocity of gases through the furnace, when running at rating, is about 7 ft. per sec. With horizontal return-tubular boilers, which most closely approach the above conditions, some authorities figure on 4 sq. ft. of heating surface to a cubic foot of combustion space.

Where the available furnace draft is considerably greater than 0.1 in. and a sufficiently long setting can be designed, as little as ½ cu. ft. of combustion space can be allowed per pound of oil burned per hour. The danger of making the combustion space too small is so much greater than of making it too large that considerable care must be used in adopting a ratio of combustion space as low as ½ cu. ft. With a large combustion space of proper design, it is obvious that higher ratings can be more readily obtained.

For horizontal return tubular boiler settings, it is usually recommended that the bridge wall be removed for oil firing as it is frequently a source of maintenance trouble and expense. In the ideal furnace, the cross sectional area increases with the flow of gases; the floor is rounded off and rises toward the back to deflect the gases upward. The walls should be lined with a good quality refractory and should be of sufficiently heavy construction to withstand the temperature conditions of the furnace.

It is good practice to put a layer of insulating brick between the lining and the outside common brick. The setting should be made tight to prevent leakage of air into the furnace, as this air is not required for combustion and every pound that enters the furnace in this way

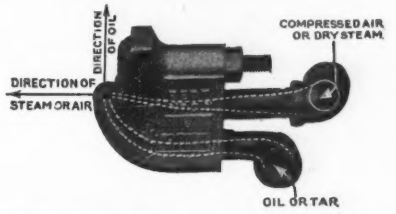


FIG. 2. THE BEST BURNER IS OF THE OUTSIDE MIXING TYPE

will carry up the stack a certain amount of heat which is a dead loss.

In changing over from coal burning, it is usually necessary to remove the grates and bring the furnace floor to the ground level, removing the bridge wall. The burners are then placed in the ash door, the fire door removed and the opening bricked up, leaving a small hole for observation purposes. With stoker installations having a sufficiently high setting it is possible to cover the grates with a layer of fire brick and fire directly over it. This makes it possible to revert to coal burning on short notice.

Air Supply and Distribution

One of the next important points to consider in the furnace design is the air supply, as affected by available draft and affecting efficient combustion. In this the method of admitting and controlling the combustion air is the deciding factor.

Two general methods are used for handling the admission of the air, the use of an air register and the use of a checker-work grill. The air register usually forms a part of the burner as illustrated in views of different types of burners and the air admission is controlled by the port opening and up-take damper.

Where air is admitted through the furnace floor, as illustrated in Fig. 1, the quantity is controlled by the up-take damper and, in some cases, by an additional damper in the incoming air duct.

In the construction shown in Fig. 1, the openings in the furnace floor run at right angles to the direction of the flame. These openings are usually 1 to 2 in. in width and extend across the furnace as shown. The air should be distributed beneath the atomized oil as it comes from the burner tip to not greater than 6 ft. depth into the furnace. The usual method is to draw the air through openings in the base of the front wall which lead into ducts that carry the air to the openings in the furnace floor. One large air opening in the furnace floor is undesirable, as this results in intense heat at the point of contact with the oil vapor and in incomplete combustion in other parts of the furnace.

Five to ten rows of openings between bricks, each opening separated by the width of a brick, has been found in practice to give good distribution of air throughout the oil vapor. The total effective area of air openings in the furnace floor will vary with the draft

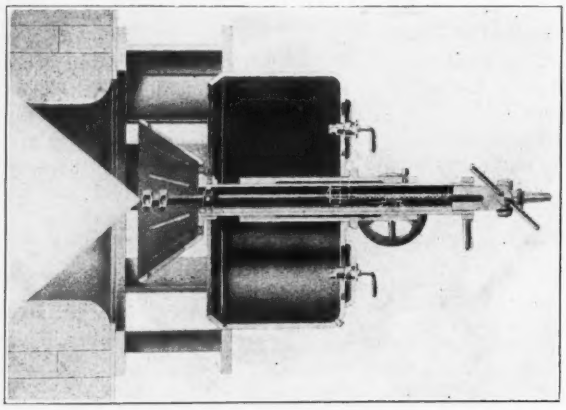


FIG. 3. BETHLEHEM MECHANICAL ATOMIZING BURNER SHOWING ARRANGEMENT OF REGISTER

conditions but, if 3 sq. in. is allowed per rated boiler horsepower, no difficulty is experienced in getting 14 per cent CO_2 provided the setting is tight. With higher drafts, less than 3 sq. in. may be allowed although more

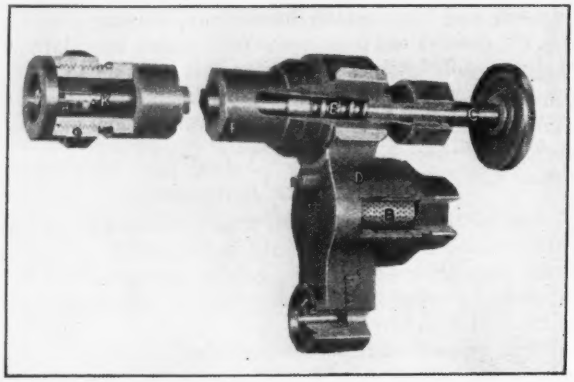


FIG. 4. IN THE COEN BURNER REGULATION IS OBTAINED BY A SPECIAL TIP

would do no harm, since the draft may be cut down at the up-take to give the desired rating.

Two Types of Burners Used

After considering some of the points of furnace design which apply to the problem of burning fuel oil, the next step is the consideration of the type of burner to be chosen. Two types, those which depend on the use of steam or compressed air for atomizing the oil and those which depend on centrifugal action to break up the oil into fine particles are in general use.

Further classification of steam or air atomizing burners is made into those in which the steam or air comes in contact with the oil before reaching the tip and those in which the atomizing agent and oil meet at the tip of the burner. These two classifications are sometimes referred to as the inside and outside mixing types.

With the steam or air atomizing type, either the checker-work method or the air register is used for admitting the combustion air. With the mechanical atomizing type, the air register method is used.

Many burners are available using these principles to secure efficient combustion of fuel oil. In the following paragraphs, the principal features of some of these burners are presented.

An outside mixing type of burner in which the steam and air meet at the burner tip is illustrated by the burner built by W. N. Best Furnace and Burner Corporation. As shown in Fig. 2, the air or steam meets

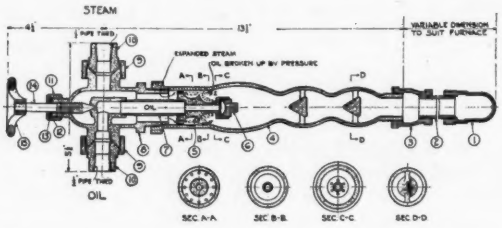


FIG. 5. THE QUINN BURNER IS OF THE INSIDE MIXING TYPE

the oil at right angles. Air or dry steam at a pressure from 15 lb. up is used for atomizing and the oil pressure need not be over 10 lb.

Mechanical atomization is used in the burner built by the Bethlehem Shipbuilding Corporation. As shown in Fig. 3, the burner consists of a tip of special design mounted on the end of the burner pipe, which extends into the furnace front through an adjusting pipe. On

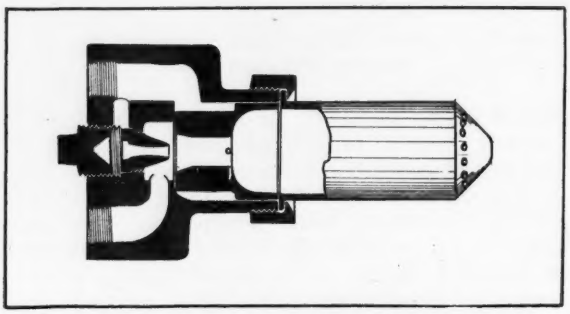


FIG. 6. AN AIR REGISTER IS USED WITH THE ENCO STEAM ATOMIZING BURNER

the end of the adjusting pipe is a cast-iron cone, or deflector, which is made in various sizes, depending on the type of front installed. The cone can be adjusted by moving in or out to the position where the flame will receive the proper amount of air for good combustion.

It is possible to regulate the supply of air to the burner by adjusting the area of the air inlet, by means of a rack and pinion attachment fitted with a hand wheel, by which the register check can be positioned for the admission of the required volume of air.

Regulation in the mechanical atomizing burner manufactured by the Coen Co. is obtained by a special tip construction. The regulating rod shown at C in Fig. 4 has a rotative movement of ¼ in. When turned to the extreme left, the burner is wide open delivering the maximum fire. By turning the rod to the right, the fire is gradually diminished until the pin K is brought into

contact with shoulder of burner tip H when the minimum or stand-by fire is produced. The rod cannot be turned far enough to extinguish the fire, as this is purely a regulating valve. The burner fits within an air register having a large number of valve blades to give the air its proper rotation.

The burner built by the Combustion Engineering Corporation and known as the Quinn, is of the inside

FIG. 7. FOERST BURNER OF THE CONICAL FLAME TYPE

mixing type. As shown in Fig. 5, oil is forced by pump or gravity pressure through the passageway 7 and, reversing its direction of flow, is forced through the small openings (Section C-C) striking the abutment 5 where, by virtue of its momentum, it is atomized.

FIG. 8. BURNER CAPACITY MAY BE VARIED BY CHANGING PLATES IN LOCKETT BURNER

The oil thus atomized continues along the abutment to its edge, where it is picked up and further atomized by the expanding steam coming through the openings shown in section A-A. In this almost gaseous state it is then carried by the steam to the burner tip.

In the method of oil burning developed by The Engineer Co. and known as the Enco S. A. R. system, a steam atomizing burner producing a hollow cone spray is used with an air register. In this burner, as shown in Fig. 6, a current of steam passing down and through the nozzle tube meets the oil coming up. A number of small jets of steam issue from the tangential holes, giving the mass of oil and steam a whirling motion, which continues until the mixture blows out of the opening in the form of a hollow cone spray.

With this burner, a register is used in which the air is drawn through the front. The entering air is set in rotation by adjustable shutters set at any desired angle. Secondary air for ignition and cooling is admitted around the burner through a small central register, which is provided with a rotating damper. The furnace opening of the register is constructed of fire brick of venturi shape.

An inside-mixing steam atomizing burner is built by the John Foerst & Sons Co. as shown in Fig. 7. A

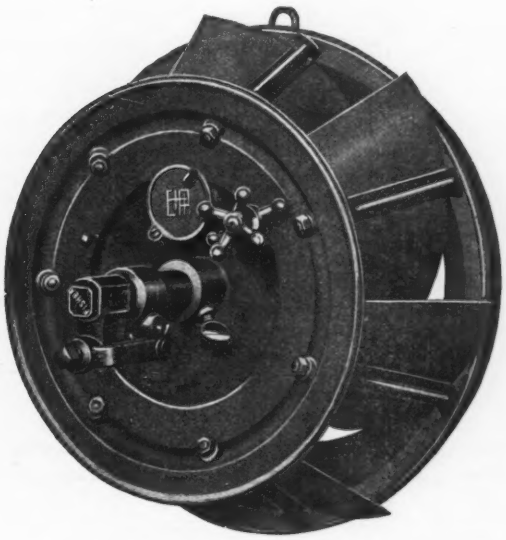


FIG. 9. PEABODY FISHER BURNER WITH AIR REGISTER

burner of this type gives a conical flame although burners of the fantail type are also built by this organization.

Another burner of the outside-mixing steam atomizing type is the Lentz, built by B. P. Lentz & Co. The nozzle head is made up of two castings, separated by three disks. Regulation is obtained by adjustment of the oil and steam valves.

One feature of the burner made by A. M. Lockett and Co. is a multiplate construction by which the burner capacity may be changed. This burner is of the outside mixing type using steam for atomization. As will be noted from Fig. 8, the amount of burner opening may be changed by taking out or inserting plates. It is possible, for instance, to convert from 100 hp. maximum efficiency to 500 hp. maximum efficiency by changing two plates. The burner may be used for either front of back shot firing.

The burner manufactured by the Morse Dry Dock and Repair Co. is one of the mechanical type in which regulation is obtained by an adjustable sleeve. This sleeve has a helical slot which is uncovered more or less by the top of the atomizer to control the amount of oil entering the burner passage. The tip contains a conical

cavity ending in a small orifice through which the whirling oil issues. An air register having adjustable vanes directs the flow of air through the oil cone.

One feature incorporated in the mechanical atomizing burner of the Peabody Engineering Corporation is the method of securing a wide range of operation, by providing a secondary outlet from the central chamber so that either all the air may pass out of the orifice in the form of spray or any desired portion of it may be returned through the bypass.

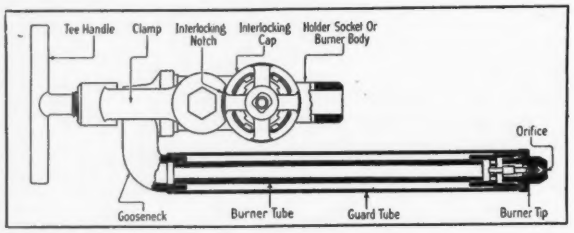


FIG. 10. MECHANICAL ATOMIZING BURNER OF SCHUTTE AND KOERTING

Figure 9 gives an idea of the air register which is used with this burner. When assembled, the burner and diffuser pipe, which are joined by means of a coupling, are longitudinally adjustable, so that the location of diffuser and tip with respect to the opening in the furnace may be varied.

Flexible metallic hose connections are provided for attaching the inlet and outlet oil conduits to the pipe lines.

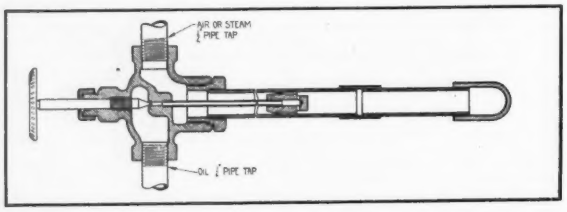


FIG. 11. TATE-JONES AIR OR STEAM ATOMIZER

Burners built by the Schutte & Koerting Co. are of three types, high-pressure mechanical atomization, low-pressure air atomization and the air-pressure steam or air type. Figure 10 shows the mechanical type where atomization is produced by forcing the oil, under a pressure of 125 to 250 lb., tangentially through a circular chamber, so arranged as to give the oil a high velocity of rotation and thus under the action of centrifugal force to break it up into a finely divided fog of particles. The circular chamber, or tangential groove, discharges into a small cylindrical chamber, the tip end of which is coned out. At the apex of the cone is the orifice through which the oil is discharged into the furnace.

Air is introduced through a register and is mixed with the atomized oil. This air register can be adjusted to supply the right amount of air for any rate of combustion.

Either air or steam is used with the inside-mixing burner built by Tate-Jones & Co. Full pressure on the oil is maintained up to the point where it is mixed within the burner. The steam parts of the mixer surround the oil parts and the finely broken up oil is thus maintained at practically the same temperature as the steam

Gas Can Be Burned with Higher Efficiency than Other Fuels

FOR gaseous fuels, no distillation or atomization is necessary. All that is required is to mix the gas with air in a combustible mixture and the chemical combination takes place almost instantaneously. Great economy of both time and space may, therefore, be obtained. If the initial mixing is properly done, it is possible to burn gas completely with as little as 5 or 6 per cent excess air.

It is important in burning gas, as in burning any other fuel, that the combustion chamber be of the right size. Practice varies somewhat, but 0.2 cu. ft. per sq. ft. of heating surface or 2 cu. ft. per boiler horsepower is a fair average. The gas pressure varies with the length of gas passage in the furnace, but ordinarily should be kept at from 2 to 8 oz.

Velocity of the fuel at the nozzle should be greater than the rate of propagation of the flame, but not so great that unconsumed combustible reaches the first pass of the boiler. This velocity, for best results, should

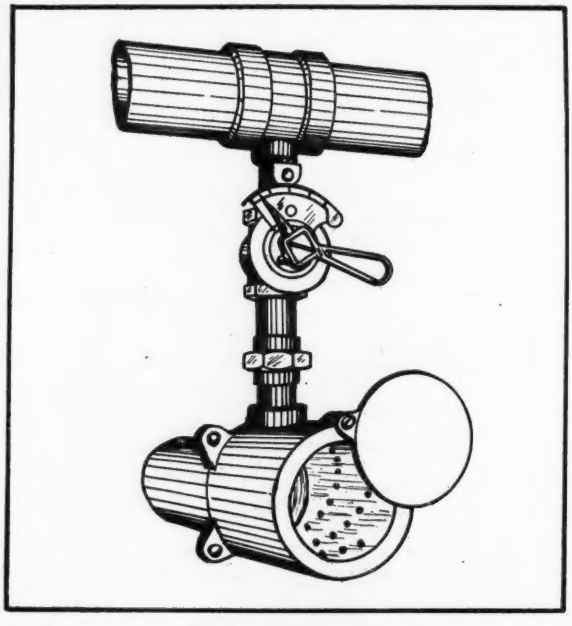


FIG. 1. GAS IS FED IN TOWARD THE CENTER OF THE MAIN NOZZLE THROUGH NUMEROUS SMALL NOZZLES IN THE INNER CASING

be as near the rate of propagation as possible. If, however, it is too near, pulsations in the flow will cause flarebacks. The rate of propagation of the flame in a perfect mixture of combustible and air is about 1000 ft. per sec. As the mixture is not perfect at the burner, this velocity will be reduced to about 700 ft. per sec.

Total area of the passage for gas and air at the burner should be about 1.6 sq. in. per boiler horsepower. No one burner should be expected to carry more than about 30 hp.; in other words, the total area of a burner should not exceed about 50 sq. in. or the diameter should not be greater than 8 in.

The ratio of the areas of the gas and air nozzles varies with different gases as, in general, each gas requires a different quantity of air for complete com-

bustion. For equal volumes, natural gas requires about 12 times as much air as blast furnace gas, hence for these two gases the areas of the nozzles should be in this proportion.

Types of Gas Burners

In a general way, burners are built on the Bunsen principle, i. e., the velocity of the fuel gas through a tube induces a flow of the air for combustion. A Bunsen flame, however, carries a considerable excess of air, which is undesirable in a boiler furnace, consequently the air ports for this class of work have less area in proportion to the gas ports than do those of a Bunsen burner.

Gas is introduced under a pressure of from 2 to 8 oz. into the mixing chamber of the burner in one or more jets in such a direction that the movement of the gas induces a flow of air through the mixing chamber into the furnace. Typical examples of burners are shown in Figs. 1 and 2. The first burner consists of two concentric casings and a nozzle. The annular space between the two casings is the gas chamber. Through the inner casing are driven a number of small studs which are drilled through in such a way that the jets enter the mixing chamber with a swirling motion that is effective in producing a complete mixture of the air and gas. The burner shown in Fig. 2 consists of a gas

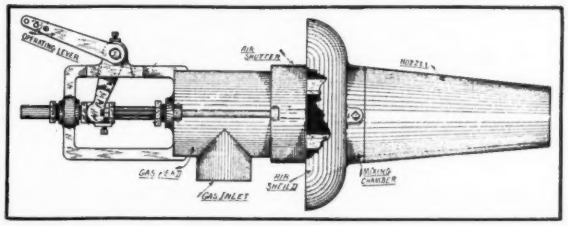


FIG. 2. QUALITY OF MIXTURES IS CONTROLLED BY THE AXIAL MOVEMENT OF A SLEEVE OVER THE GAS HEAD

head which discharges into a converging nozzle carrying an apron or air shield at its base. Control of the air supply is effected by a cylindrical air shutter which may be moved axially along the end of the gas head.

In installing these burners, the end of the discharge nozzle is placed approximately on a line with the outside surface of the boiler wall, an aperture being cut through the brickwork of the front wall with an area somewhat in excess of that of the burner nozzle. This opening diverges inward to allow for the expansion of the mixture as it becomes heated. Through the annular space thus provided around the nozzle, additional air is supplied for combustion. The movement of air over the top of the burner is also effective in preventing overheating at that point.

Where more air is required than can be admitted through the burner openings, holes are cut through the brickwork which forms the floor of the combustion chamber. Such additional air passages should be close to the burners so as to reduce any tendency toward a long flame. When it is necessary to admit secondary air in this manner, it is usual to place a refractory baffle in the path of the flame to promote intimate mixing. Except for this, burners should be so arranged that there will be no impingement on the brickwork in the furnace, as this results in excessive erosion.

In considering the subject of gas burners, some thought should be given to the question of surface combustion. An arrangement for this is shown in Fig. 3. With this device a high-velocity jet of combustible mixture is directed against a bed of refractory material on the floor of the combustion chamber. When the furnace is lighted up from cold there is, at first, an irregular flame issuing from the pores through the bed, but as this refractory material becomes heated, the flame becomes shorter until it finally dies away completely, leaving a bed of incandescent material throughout which

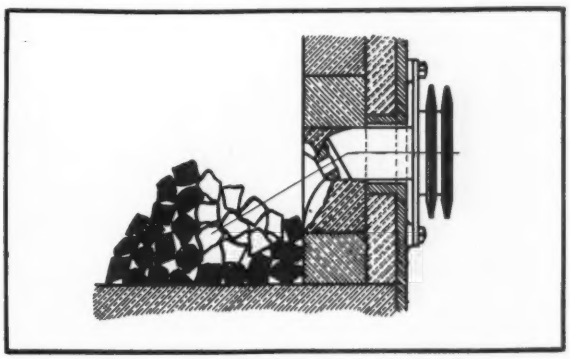


FIG. 3. IMPACT TYPE OF BURNER USING REFRACTORY BED

flameless combustion takes place on the surface of the material. Because of the high velocity of the jet, which is considerably in excess of the rate of flame propagation, no burning takes place in the jet itself.

As an illustration of the advisability of using equipment suited to the load to be carried, L. C. Kemp, in Engineering of London, estimates that in the Blackburn generating station, by installing a 3000-kw. unit to carry the night load, 800 kw., instead of using a 10,000-kw. unit, the steam consumption would be reduced 4850 lb. an hour, and 55 kw. saved on power required by auxiliaries. The coal saving would be 2.5 T. per shift or 1130 T. for a 4000-hr. year.

As an offset, however, if the 3000-kw. unit were to be installed for this use only, Mr. Kemp estimates the cost, including foundations and proportion of station at about $90,000, the charge on which for interest, depreciation and taxes would be some $9000 to $12,000, a greater amount than that saved in coal cost. So that it would not be economy to install the small unit unless other uses than carrying the night load were in view.

The presence of carbon monoxide gas in the uptake of a boiler indicates one or more of the following conditions: Poor design of furnace, improper methods of firing, poor fuel and equipment for burning it, improper mixing of the combustible gases with the air, low furnace temperature so that the gases are cooled below the ignition point, deficient air supply, molten fuel bed, fusion of the ash on the grates, dirty fuel bed or dirty fuel oil burners. Tests have shown that for every 0.1 per cent of CO in the uptake gases, a drop of 2 per cent in boiler efficiency results. This is not a straight line curve, but runs as follows:

Per cent CO	0.1	0.2	0.3	0.4	0.5	0.6
Efficiency, per cent..	72	63	60	57	56	54

Furnaces for Burning Wood Refuse

DIFFICULTIES ENCOUNTERED IN BURNING THE REFUSE FROM WOODWORKING PLANTS AND PRINCIPLES GOVERNING FURNACE DESIGN

SAW MILLS, wood working factories and tanneries produce as a waste product considerable wood refuse, such as edgings, sawdust and tanbark, which in many cases is sufficient to supply all the fuel necessary for the power plant. To burn this fuel efficiently, requires a furnace designed especially for the kind of fuel used.

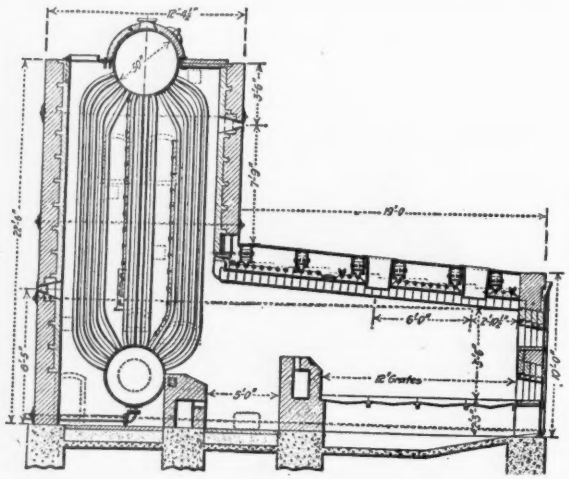


FIG. 1. DISTRIBUTION OF HOGGED FUEL ON THE FLAT GRATE IS AIDED BY PROVISION OF FOUR FEED THIMBLES

As a rule, wood refuse contains considerable moisture averaging in the neighborhood of 40 per cent; it is bulky; the fuel bed readily develops holes; fine particles of ash are carried with the gases and attach themselves to the heating surface. Some woods are subject to clinker formation when burning and in all cases the percentage of volatile is high.

Where wood refuse forms the major portion of the fuel used, the usual custom is to feed the furnace through chutes which drop it directly upon the grate; as a result the fuel bed naturally takes the form of a cone with the apex just beneath the mouth of the chute. This form of fuel bed prevents an even distribution of air and causes the development of holes around the edges of the cone, which blow holes are conductive to the formation of clinkers.

Where flat grates are employed, the formation can be broken to some extent by the use of two or more feed chutes thus causing a more even distribution of the fuel and by rotating the intervals of feeding, the combustion conditions are greatly improved. In modern practice, however, it is usual to employ an inclined grate except in cases where coal must also be fed by hand to the grate. The multiple feeding arrangement has advantages under such conditions also, as it is then possible to use one or more sections of the grate for coal without disturbing the combustion of the wood.

In the use of inclined grates, which may be either side or front feed, the object is to maintain a fuel bed which will have substantially the same air resistance throughout its entire surface. The fuel is fed at the top of the grate and slides, tumbles or is worked by the agitation of the grate bars towards the bottom end of the grate where combustion is completed and the ashes are dumped to the ashpit. The slope of the grate should be about the same as the natural incline of the fuel or a little more nearly vertical which would cause the fuel bed to be thicker at the bottom where it contains a larger percentage of ash and its relative air resistance is less.

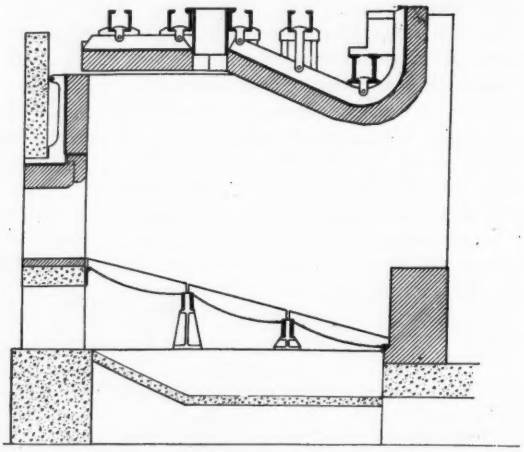


FIG. 2. THE DROOPING ARCH AND INCLINED GRATE AID IGNITION, GAS MIXTURE AND AIR DISTRIBUTION THROUGH THE FUEL BED

Even distribution of the fuel at the top of the grate is important as the fuel bed would otherwise become streaked. This can be accomplished by the use of a number of feed chutes with short spaces between them and allowing the fuel to fall upon a hearth at the top of the grate, which will aid in the distribution. Where the moisture content is not great, the hearth may be flat, or it may have the same slope as the grate and receive the reflected rays of the furnace upon it to quicken drying. Continuous feed in small quantities is always an advantage where it can be provided for, as it results in more uniform combustion conditions.

As to the furnace for burning wood refuse, best combustion conditions have been secured where the combustion space is large, provision is made for mixing gases thoroughly within the furnace, radiant heat from the fuel bed is reflected back upon the fuel and combustion of the gases is completed before they come in contact with the boiler heating surfaces. With these objects in mind, furnaces for burning wood refuse are designed with an arch extending over the entire grate surface. This arch frequently has a drooping portion at the end which aids in breaking up stratification of the gases as they leave the furnace and reflects radiant heat from the hottest part of the fuel bed back upon the green fuel as it enters the furnace, thus hastening drying and ignition.

Some designers shape the bridgewall so as to reflect the radiant heat upon the green fuel and in some cases an arch overhangs the rear end of the grate to direct a current of heated gases toward the upper part of the

grate. Air is admitted through tuyeres in the bridgewall, in some furnaces, to aid in the mixing of the gases and thus cut down the necessary furnace space.

Proportions of furnaces and provisions necessary for best combustion vary considerably with the quality of the wood burned and its moisture content. With a properly designed furnace, a conservative estimate as to the maximum capacity of a wood-burning grate is 9 hp. per square foot of grate surface with woods containing 30 per cent moisture and 4 hp. for fuels containing from 45 to 50 per cent moisture. In one plant burning hogged kiln-dried wood, principally maple, good results were secured with a furnace volume of 6.3 cu. ft. per rated boiler horsepower. The boilers were normally operated at 150 to 200 per cent rating though for short

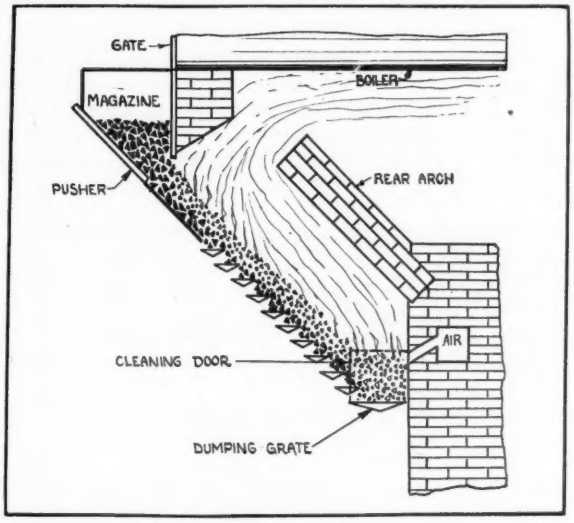


FIG. 3. HOT GASES MAY BE DEFLECTED FOR DRYING THE GREEN FUEL BY AN ARCH OVERHANGING THE REAR OF THE GRATE

periods 300 per cent of the rating has been carried. The ratio of grate surface to heating surface in this case was 1 to 70.

In Fig. 1 is illustrated a furnace designed for burning hogged fuel. The ratio of heating surface to grate surface in this case is 1 to 35 and, under favorable conditions and with good fuel, 200 per cent of the boiler rating can be developed. The grate surface is 12 by 18 ft., each of the four feed thimbles serving a space 6 by 9 ft. Air is admitted over the fuel bed through dampers in the front of the furnace and also through ports in the first bridgewall.

In burning wood refuse, the type of grate used depends to a great extent upon the arrangement of the furnace and whether natural or forced draft is used. Where the grate surface is flat and the fuel piles up in the shape of a cone 3 to 5 ft. high, a form of hollow grate bar is frequently used with a blower system. The hollow bars are usually perforated with holes ranging from ¼ to ¾ in. in diameter, depending upon whether sawdust, shavings or slabs are the principal constituents of the fuel. The grate surface is usually made up of hollow and common bars alternately.

Many engineers, however, do not recommend forced draft for burning wood refuse, particularly where the fuel bed is comparatively thin, as would be the case where the fuel is fed in units of small area, as there is a tendency to form blow holes that cut down the efficiency of combustion. In recent practice the tendency is toward the use of sloping grates somewhat on the order of the gravity stoker usually with bars stepped and running crosswise of the furnace. With this arrange-

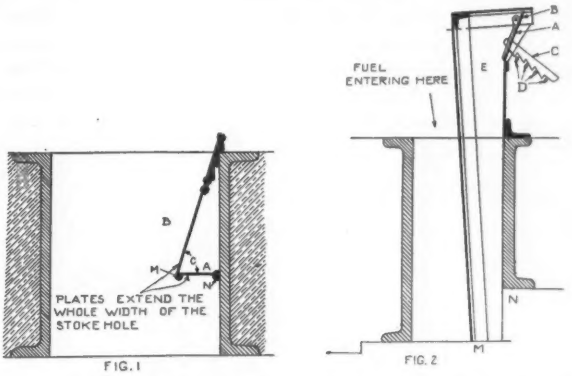


FIG. 4. DEVICES FOR CONTROLLING AIR ENTERING FURNACE THROUGH STOKEHOLE

ment the slope is usually around 30 deg. which is less than the angle of repose of the fuel, causing it to be thicker at the front than at the rear of the grate. By the use of shaking grate bars or the more modern hand stoker, the fuel bed can be kept clean and more evenly distributed.

Where gravity alone is depended upon to distribute the fuel, the slope is increased to 45 or 50 deg., which with natural draft causes a more even distribution of the air through the fuel.

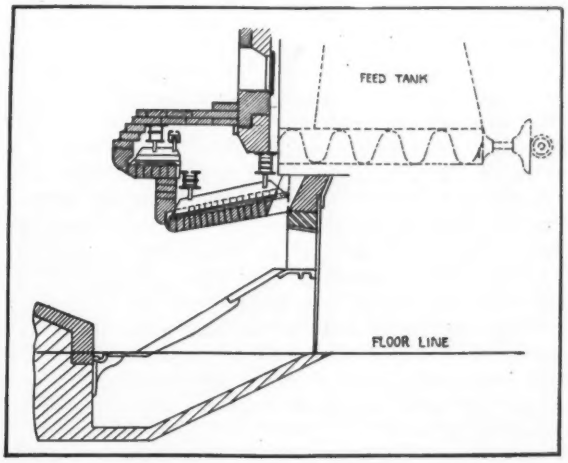


FIG. 5. ARRANGEMENT FOR USE OF SCREW CONVEYOR IN FEEDING SHAVINGS FROM STORAGE TANK

Air is supplied to the furnace by three methods: Through the stokehole or feed thimble, through the grate and fuel bed and to the gases over the fire or through ports in the bridgewall.

When the feed is continuous, either by gravity or blown in from a cyclone, considerable air enters with the fuel which may be detrimental to the operation of the furnace unless provision for breaking up stratifica-

tion is provided, as this air is drawn immediately along the roof of the furnace without mixing with the combustible gases or the burning fuel. Air from this source should be under the control of the attendant as otherwise the fixed opening of the stokehole admits air here in inverse ratio to the rate of fuel feed, hence dampers such as shown in Fig. 4 are of advantage.

Air supplied through the grates is controlled directly by the stack damper and the draft over the fire varies considerably with the quality of the fuel used, arrangement of grate and the load carried. On a hand stoker burning mill refuse, where the fuel bed does not exceed 12 in. in thickness, the draft ranged from 0.15 to 0.2 in. for best results.

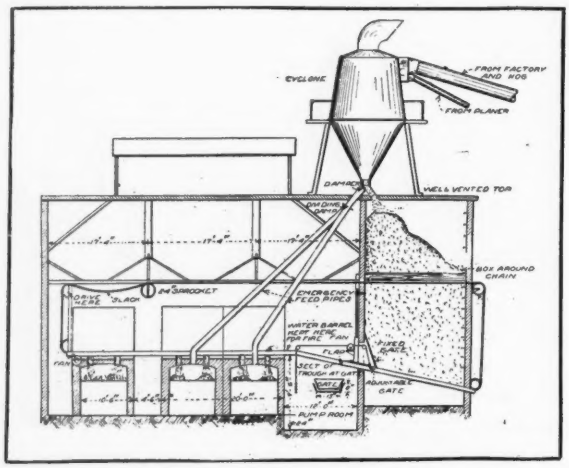


FIG. 6. AN INDEPENDENT STORAGE BIN OF LARGE CAPACITY IS PERMITTED BY USE OF CHAIN DRAG CONVEYOR

One of the difficulties encountered in supplying air through the grate is to secure an even distribution. With a flat grate and the fuel bed consisting of one or more cones, air drawn through the grate will pass most freely through the light ashy part around the edges of the cones, with insufficient air through the centers of the cones. This action is likely to result in blow holes surrounded by clinker formation. When an inclined grate is used, however, it can be so located that the natural incline of the fuel as it is being burned will keep the grate covered so that the resistance of the fuel bed will be uniform throughout its entire area. By employing some form of working grate bars, holes may be covered and clinker formation broken up. The slope of the grate must be varied with the characteristics of the fuel used, in which respect no two plants are exactly alike.

Wood fuel contains a high percentage of volatile combustible matter which requires to burn it the admission of air over the fuel bed. This additional air should be under the control of the fireman and should be so admitted into the furnace that it will mix thoroughly with the volatile gases. Some furnaces are arranged with dampers in the front wall for this purpose, others supply this air entirely through the stokeholes, as mentioned previously, while in some instances the bridgewall is designed for admitting air. The latter arrangement has the advantage that it sets up a cross current which aids in breaking up stratification of gases and the air becomes heated in passing through the duct in the bridgewall.

In the burning of wood refuse, best results are secured where the method of feeding is automatic and continuous; though in some instances intermittent feeding is advisable, particularly where the refuse is not sufficient to generate all the steam requirements, and coal must be used in addition to the refuse. A method commonly used is to feed the fuel through a blow-pipe direct from the cyclone where the sawdust and shavings are collected. This has the advantage of simplicity, but does not permit the storage of the fuel when the refuse produced is greater than the demand for fuel. It is applicable, therefore, only where the refuse does not meet the entire demand for fuel. It also presents a certain fire hazard with fine dry fuels such as sawdust; also the supply may not come to the plant regularly, resulting in irregular feeding.

Some of the objectionable features of the direct system may be overcome by providing a storage bin from which the fuel is fed to the furnace continuously and in just the quantities required by means of a screw conveyor or a chain drag. In either case, however, careful attention must be given, as the fuel is likely to

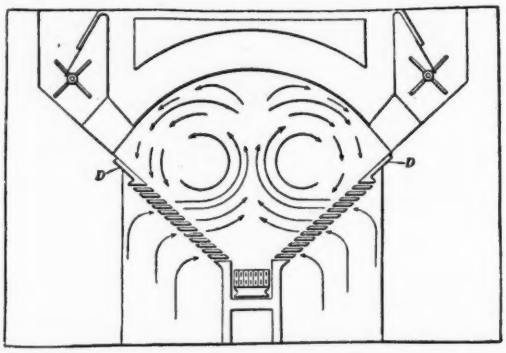


FIG. 7. SIDE FEED STOKER USING PADDLE WHEEL FEEDING DEVICE FOR WOOD REFUSE

bridge over the conveyor and fail to deliver to the furnace. With either of these conveyors, the fire hazard is reduced, as there is no direct contact between the fuel in the furnace and that in the storage bin.

Side-feed stokers sometimes employ a paddle wheel for working the fuel from the hopper to the upper end of the grates, the fuel being brought to the hopper in any convenient way. This arrangement of feeding is well adapted to installations where coal is needed in addition to the wood refuse, in which case both the coal and refuse are thrown into the hopper and the mixture is fed automatically.

Another arrangement which has worked satisfactorily in plants where the refuse forms only a portion of the fuel used is the employment of an underfeed stoker with the chute feeding directly upon the incandescent bed of coal. If the wood refuse is fine, much of it will burn in suspension, as it leaves the feed thimble. In some instances, traveling grate stokers, with furnaces especially designed for moist fuels, have been used with wood refuse. In this case the hopper may be used for feeding, but some method of agitation of the fuel in the hopper is necessary to insure continuous and even feed.

Application of Pulverized Coal to Boilers

CLOSE STUDY OF EXISTING INSTALLATIONS, DEVELOPMENT OF EQUIPMENT, AND IMPROVEMENT OF APPLICATION HAVE LED TO RAPID PROGRESS IN THIS FIELD

THERE is no more conclusive evidence as to the gaining popularity of pulverized coal than the announcements, during the past year, of its adoption by several large central stations, and numerous industrial plants. In many plants engineers are interested to the extent that they have equipped one boiler for burning pulverized coal and placed the unit upon a practical investigative basis. Such methods will lead to improvements of coal preparation, distribution, fuel burning and furnace construction, all of which will be of infinite value to the engineering public. In existing plants, investigations and changes are constantly being made with resulting great progress towards perfection.

PREPARATION OF FUEL

It is common practice to crush to a 1¼-in. diameter or less all coal which is to be used in the pulverized form. This is merely preparatory to the process of further breaking down or pulverizing the coal so that it can be properly burned. Crushers of the single, double or four roll type may be used. In the final preparation of coal for the burners, it is pulverized so that all but from 5 to 10 per cent will pass through a 200-mesh screen. It has been shown that about 70 per cent will pass through a 600-mesh screen, which indicates that a high percentage is essentially dust or impalpable powder.

Commercial pulverizers reduce the coal to proper size either by grinding or impact, or a combination of the two. The accepted method of removing the pulverized coal from the pulverizer is by means of an air blast, as in this way, only the fine coal is carried to storage or the burners. A change in blast intensity will vary the quantity and size of coal carried from the pulverizer.

Coal storage in powdered fuel plants is concerned first with the storage of raw coal which has been crushed. In the unit system this crushed coal is fed to the pulverizer, whence it is taken directly to the burners. In this case, the coal storage involves no more complication than would be encountered in an ordinary stoker installation. In this system, the air of separation picks up the coal in the pulverizers and conveys it directly to one or more simple burners at the furnace. But the air of separation may not be sufficient to support complete combustion, therefore the additional air required is drawn in around the burner and through special air openings in the furnace walls.

DRIED PULVERIZED COAL MAY BE STORED

When the coal is to be dried it is delivered from railroad cars to a track hopper from which it is fed to the crusher by a plate feeder or an apron or belt conveyor. An elevator is an economical means of delivering coal to the crushed-coal storage bin, from which it is taken by a feeder for delivery by gravity to the dryer. At the discharge end of the dryer, another elevator discharges the coal into the dry-coal bin from which it is fed by gravity to the pulverizer. Air at low pressure carries the coal from the pulverizer to the collector whence the coal is conveyed to the powdered coal bin by means of a screw conveyor. In some systems, but one powdered coal storage bin is used from which the coal is taken by a screw conveyor and fed into the suction side of a blower. The coal is then transported by air to the burners. A return line conducts the coal not used at the burner to the storage bin to be fed over again. After the coal is extracted, the air from the return line returns to the distributing blower.

When pulverized coal is stored, it must be taken from the pulverized-coal storage bins by some form of screw conveyor. This conveyor may discharge into a separate mixing chamber into which part of the air for combustion is admitted, or the coal may fall by gravity to the burner where it is picked up by an air blast. In some types, a small amount of air picks up the coal at the end of the conveyor and transports it to the burner where additional air is admitted for mixing and combustion. In one system, a second mixing chamber is provided at the burner, so that practically 100 per cent of the air of combustion enters the burner nozzle with the coal.

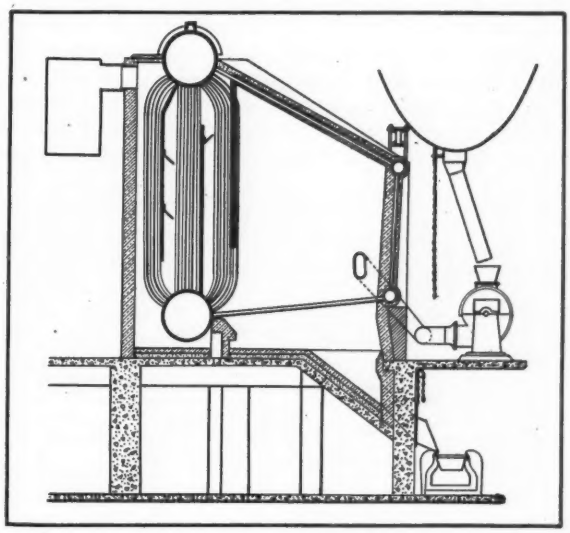


FIG. 1. UNIT SYSTEM IN WHICH PULVERIZED COAL IS FED DIRECTLY TO BURNERS

Storage bins for the crushed and dried coal need be of no different construction from those used for stoker coal. Bins for powdered-coal storage should have sides which slope 60 deg. or more in order to keep the coal from packing and adhering to the walls, in which case it may arch across and cause an interruption of the coal supply. Bins for this latter purpose may be of steel or concrete, but condensation is more likely to occur with steel than with concrete.

Pulverized moist coal should not be stored because it does not flow readily but cakes over and so introduces an operating difficulty. Provision should be made for keeping the coal moving and, in the case of a plant shutdown, coal should not be left in the storage bins for any great length of time. It is always well to give the coal

time to cool between the pulverizing machine and the storage bin.

Furnace Design Is Important

Successful use of powdered coal for the generation of power depends greatly on the design of the furnace. The coal must be burned with a small excess of air and, since it will be expected to obtain a high efficiency over an extremely wide range of boiler rating, the furnace must be so designed as to withstand this service without high cost of maintenance and of refuse removal and without the necessity for taking the unit out of service at frequent intervals.

Under present requirements, the structural design of the furnace has become an important problem. The method of wall building formerly in common use is inadequate and it appears to be desirable to employ structural supports so that the refractories may be used, not for outer structural strength, but for the functions of heat resistance and insulation. Hollow-wall furnace construction has lately received a great amount of attention. In general, this construction consists of a steel casing suitably braced with a steel frame. Inside the

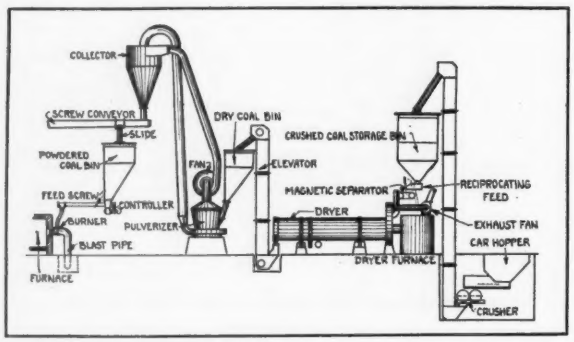


FIG. 2. DIAGRAM OF A COMPLETE PULVERZED FUEL SYSTEM

casing is placed a 5-in. layer of insulating material securely fastened to the structural frame. A 9-in. refractory wall is then built at a distance of about 9 in. from the insulating material, thus having a 9-in. air space, the refractory material being tied to the frame by special spacer blocks. About 60 per cent of the air needed for combustion is heated as it passes through this space on its way to the combustion chamber. This air space serves three purposes; it heats the air for combustion, it cuts down the loss due to radiation and it keeps the refractory lining cool, thereby reducing the erosion on the furnace side.

Initial cost of this type of furnace is a little less than it would be for the old style solid brick wall. Maintenance is at a minimum because the steel frame, casing and 5-in. lining are permanent; it is necessary to replace only the 9-in. refractory wall.

Ash Removal Facilitated by Water Screens

Water screens have come into common use. These serve not only to keep the ash-depositing zone at the bottom of the furnace cooled below the fusing temperature of the ash but also to protect the furnace wall in general from destructive heat when the boiler is operating at 300 to 400 per cent of rating with a high CO_2 content in the gas. The water screen also produces an additional evaporating surface at a low initial and operating cost. It absorbs heat at a rate above 40,000 to 50,000 B.t.u. per sq. ft. of heating surface per hour. Development of the screen has made possible the easy removal of ash through hoppers or doors.

Furnace volume for use with pulverized coal must be larger than for either stoker or hand-fired installations. Modern practice is indicated by the following figures which show furnace volume in cubic feet per rated horsepower; Lakeside station 4.86, River Rouge plant 4.98 and Cahokia Station 6.52. At efficiencies of about 80 per cent and without economizers, B.t.u. fired per hour per cubic foot of furnace volume is 22,000.

Safety Rules Should Be Observed

Operation of pulverized fuel plants should be in the hands of men familiar with the equipment and its care. It is not unusually dangerous provided that a few simple, safety-first rules are established and observed. All parts of the preparation and distributing plant should be dust tight. Wood should not be used in the construction of any containers. Fuel should not be allowed to accumulate where it may be dislodged and scattered through the air and dust should be swept up, not blown off with compressed air.

Discharge gas temperature from dryers should not exceed 400 deg. F. In shutting down, all coal should be fed from dryers, pulverized fuel bins and pulverizers. When starting up a furnace, the stack damper must be open and the feed air turned on full. When closing down, be sure that the fuel feed is entirely stopped before feeder air is shut off. Do not attempt to light the furnace burners from the incandescent furnace walls. Light the burners with oily waste or by a light wood fire.

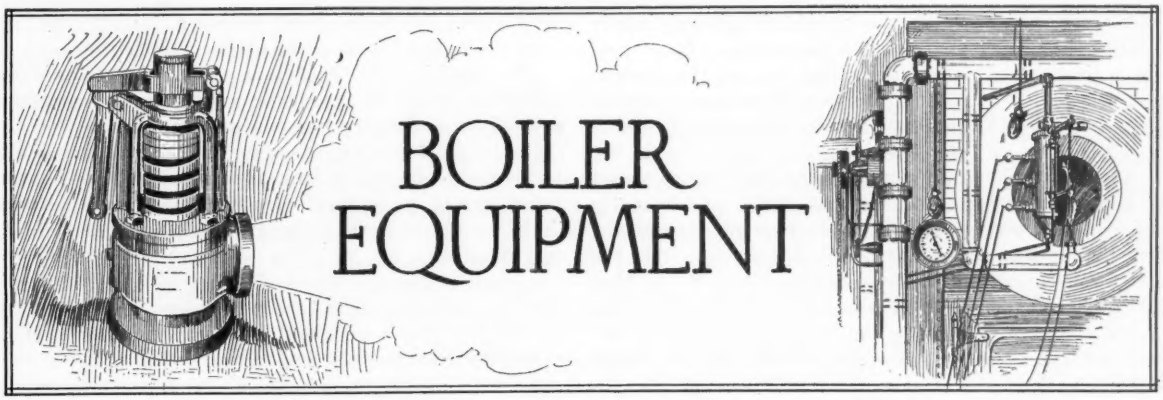
All moving parts of the equipment must be kept well lubricated. Do not enter any tanks without first airing them. A small fire or smolder may be smothered by closing all openings.

One considerable item in the cost to the consumer of machinery, equipment and supplies used in plants is the charge for transportation. Much study is being given to methods for reducing this charge and one suggestion in a recent bulletin of the Chamber of Commerce of the United States is the combination of small shipments into larger ones—carload lots, if possible—consigned to a public warehouse, located central to the final distribution of the small lots. At the warehouse, the small lots can be separated and shipped on to their destinations.

It has been found that the saving in cost by the long shipment in a large lot will more than pay for the warehouse charges, besides securing quicker delivery and the arrival of goods in better condition.

The warehouse can also be used often for storing a reserve supply from which small local orders can be quickly filled.

When a shipment of wire rope is received which is not to be placed in service immediately, see that it is stored away in a place protected from the weather and acid fumes. It is advisable to coat the outside layer of the reel or coil with a good lubricant.



BOILER EQUIPMENT

A Description of Standard Types of Water Columns, Steam Gages, Fusible Plugs, Safety Valves, Steam Outlet Valves and Blowoff Valves

SINCE the major parts of a boiler installation are the boiler itself, the furnace and the stoker equipment, these parts usually receive most of the attention when it comes to designing a plant. There are many details which, although they may seem small when considered individually, have an important bearing on continuous and safe operation. In the articles which follow, some of these details such as water columns, steam gages, fusible plugs, safety valves, blowoff and steam outlet valves, and piping will be taken up to give an idea of modern practice.

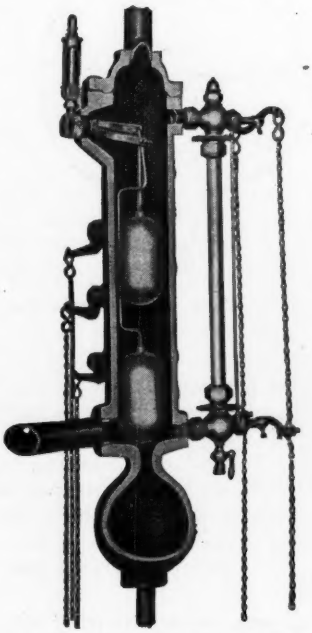


FIG. 1. SAFETY ALARM COLUMN USING FLOAT FOR HIGH WATER AND FLOAT FOR LOW WATER

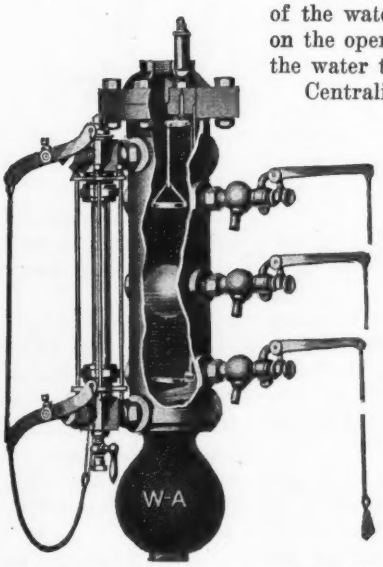


FIG. 2. BALL FLOAT OPERATES BOTH HIGH AND LOW WATER ALARMS

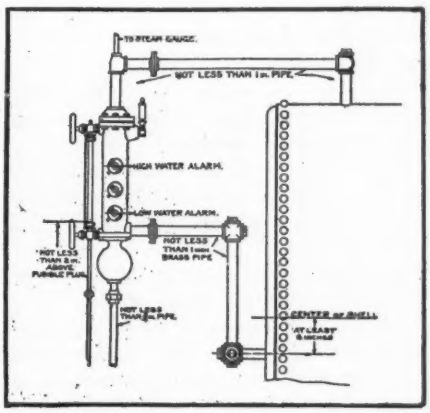


FIG. 3. WATER COLUMN CONNECTED IN ACCORDANCE WITH A. S. M. E. BOILER CODE

Due to the use of higher operating pressures, the problem of water column design has become increasingly difficult. Through the use of forged steel columns and, in some designs, the use of monel metal fittings, columns are now available for 500 lb. pressure. The next step, that is up to 1200 lb., remains to be made although a number of designs have been built for experimental purposes.

In Figs. 1 and 2 are shown two water columns, of the safety type, which illustrate modern practice. Other designs are also available, the main difference being in the method of securing the float action which operates the high and low-water alarms.

Although the whistle remains the general choice as a signal for high or low water, there is coming into use the electric method in which a gong or lights or a combination of both are used. Another development is a recorder for the water level, which, by taking a curve of the water-level conditions, gives a continuous check on the operation of feed-water regulators as well as on the water tenders, where hand regulation is used.

Centralized control for the boiler room and the increased height of boiler settings have been two factors which have caused a demand for remote water level indicators. Instruments of this type, with either the indicating or recording features are now on the market and may be used as an adjunct to the regular water column equipment.

As the installation of a water column seems to be a simple operation it is rather surprising that mistakes are frequently made. The most important point to remember is that every part of the steam pipe connecting the column to the boiler should drain either into the column or into the boiler. It makes no difference what type of

column is used; any sag or pocket in the piping is fatal to the proper operation of the column. Condensation collects at the lowest point and cuts off the circulation of steam to the column so that the water glass and floats indicate a water level higher than actually exists in the boiler.

Piping troubles are not confined entirely to water pockets in the steam connections. In a case recently noted, a new return-tubular boiler was burned out the first time it was put on the line. It was found that the water column piping was connected in such a way that the lower water connection was higher at the boiler than at the column. Naturally, the column indicated a certain amount of water regardless of how low the water fell in the boiler. It is important to remember that the

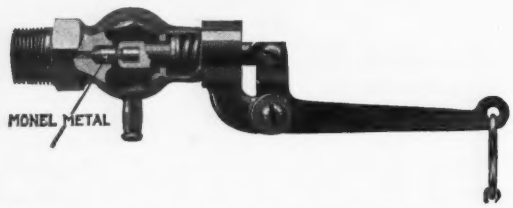


FIG. 4. LEVER TYPE OF GAGE COCK WHICH MAY BE OPERATED BY CHAINS FROM FIRING FLOOR

steam connection may drain toward either the boiler or the column but the water connection must always drain toward the boiler.

Another mistake sometimes made is the failure to set the column at the proper water level. If the column indicates the water level safe, when actually it is below the tube line of a return-tubular boiler, that water column is obviously about as useful as if it were setting out in the alley.

In order to insure the correct installation of columns, the American Society of Mechanical Engineers has included the subject in its Boiler Code. A piping layout which is in accordance with this code is shown in Fig. 3. This code calls for a minimum size of 1 in. for the pipes connecting the water column to the boiler while the blowoff pipe must be not less than ¾ in. The water connections must be of brass and provided with a cross to facilitate cleaning.

When connecting a water column to a horizontal return-tubular boiler, the steam connection must be taken from the top of the shell or the upper part of the head and the water connection from a point not less than 6 in. below the center of the shell.

No outlet connections, except for damper regulator, feed water regulator, drains or steam gage may be placed on the pipes connecting the water column to the boiler. When shutoffs are used on the water column connections, they must be either outside screw and yoke gate valves or stop cocks with levers, and such valves or cocks must be locked or sealed open.

This code also requires that the lowest visible part of the water glass be not less than 2 in. above the lowest permissible water level. The lowest permissible water level shall be that at which there will be no danger of overheating any part of the boiler when it is operated with the water not lower than that level. It is also specified that the low alarm, which blows when the water level reaches the center of the lower gage cock, must sound before the level reaches a line not less than 2 in. above the lowest permissible water level.

In addition to cautioning about avoiding any pockets or traps in the steam connection, the code suggests the use of extra heavy pipe and fittings.

It is the general practice to blow down the columns at least once in every 8 hr. of operation. The blowoff valve should be opened slowly, as too rapid blowing down causes the floats to pound on the stops and in time may dent them.

Alarm water columns are safety devices and should not be used to indicate when the feed water is to be regulated. The water level of a boiler should be maintained by watching the gage glass rather than by waiting for the alarm to operate. It is advisable to test the alarms at regular intervals. The low-water alarm may be tested by blowing down the column while the high alarm may be tried out when the boiler is banked or cut off the line.

Although gage and try-cocks operated by a wooden hand-wheel have had extensive use, the lever operated types are becoming quite popular, for two reasons: first,

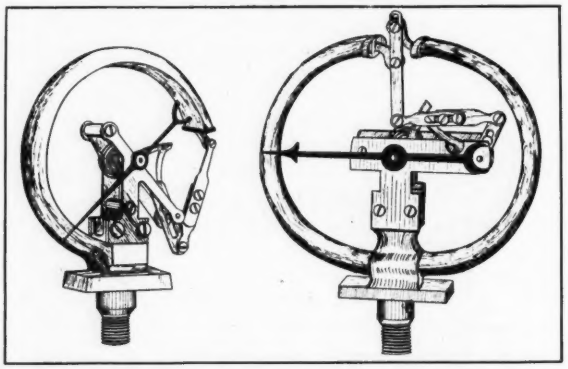


FIG. 5. STEAM GAGES ARE MADE WITH BOTH SINGLE AND DOUBLE BOURDON TUBE ARRANGEMENTS

high pressures have increased the hazards due to gage glasses breaking, and second, boiler settings are so high that the use of chains or rods with the lever try-cocks facilitates checking the water level without climbing to the gage glass level. Also, when a gage glass breaks, a pull on the chain cuts it out of service without the operator having to be exposed to the steam.

In Fig. 4 is shown one type of lever-operated gage cock.

Many types are available, some being equipped with emergency closing devices to protect against gage glass failures. Sometimes a ball valve is used as an adjunct to the lever-operated valve. If the glass breaks, the ball valve closes.

The Steam Gage Feels the Pulse of the Boiler Plant

Steam pressure gages, as employed today for whatever kind of service, are a highly standardized product as far as fundamental principles are concerned. True, there is some slight variation in external appearance to suit the artistic sense of the various manufacturers of these instruments, but such variations are of no consequence from an engineering point of view.

All indicating gages make use of the principle of the Bourdon tube, which has an elliptical cross section

and is bent in the form of a segment of a circle with the major axis of the cross section, perpendicular to the plane of the circle. When pressure is applied inside this tube, the section tends to become circular; as a result of this tendency the tube as a whole tends to unroll, so to speak, and become straight. The movement of the end of the tube is applied through a linkage system to an indicating pointer that reads gage pressure on a properly calibrated scale.

In practice this tube is either fixed at one end, as shown at the left in Fig. 5, in which case the movement of the free end is used to actuate the pointer, or it is

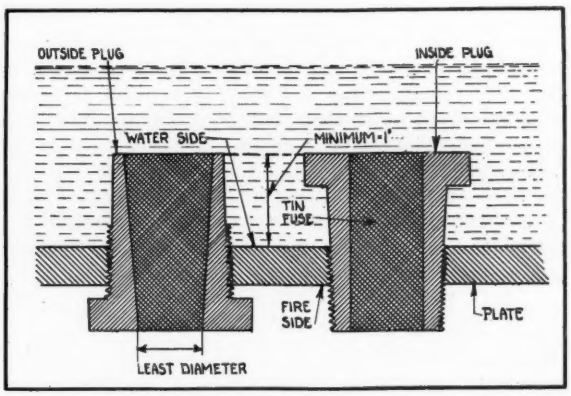


FIG. 6. FUSIBLE PLUGS INSERTED IN SHELL OF BOILER

fixed at the center, as shown at the right, in which case the relative movement between the two free ends is used.

To insure the proper degree of sensitiveness in the instrument, the moving parts are made as light as possible commensurate with the necessary strength. This construction results in rather a delicate instrument

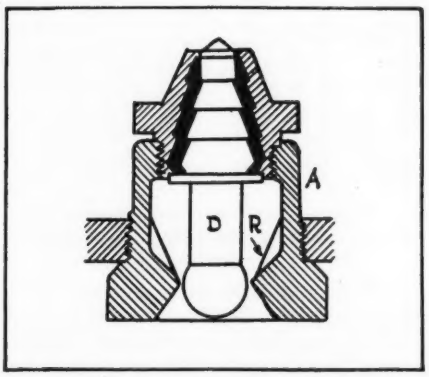


FIG. 7. THIS TYPE OF PLUG IS HELD SUSPENDED IN THE SHELL AFTER THE PLUG HAS BLOWN

which will suffer, just as any clock would, from excessive vibration. To minimize vibration in the moving elements, it is usual to separate the mechanism from the gage casing as completely as possible. This may be accomplished by mounting all the moving parts as a unit on a base fitting through which the connection to the boiler is made. The double-tube arrangement is less susceptible to damage from vibration than the other and is, consequently, better suited for locomotive work. The single-tube gage is ordinarily used in stationary practice where the vibration is not as severe.

For ordinary boiler pressures, the tube is usually made of a bronze composition. For higher pressures such as are now coming into favor, nickel spring steel may be employed.

Boiler codes specify that the dial of the steam gage shall be calibrated to not less than 1½ times the maximum allowable working pressure on the boiler; to com-

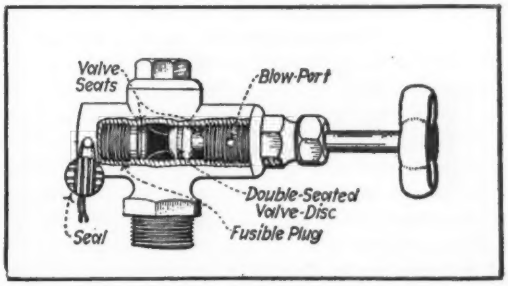


FIG. 8. A SEALED TYPE OF FUSIBLE PLUG

ply with this ruling on high-pressures of the order of 600 lb., the graduations become extremely small even on large-faced dials. In order that a variation in pressure of 10 or 20 lb. be discernible, it is well to provide two gages, one covering the whole range and one covering only the region of the normal working pressure.

In order that a gage may be kept in calibration, it is essential that the temperature should be kept fairly constant; i. e., no steam should be allowed to come into contact with the Bourdon tube. To eliminate the possi-

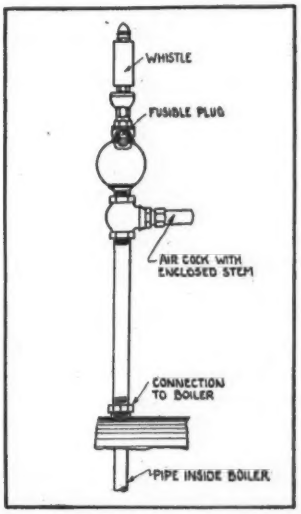


FIG. 9. FUSIBLE PLUG USED IN CONNECTION WITH A WHISTLE ALARM

bility of such an occurrence the connection to the boiler is provided with a syphon consisting of one or more loops of tube. Before starting up a new boiler this tube should always be flooded.

Unless the center of the gage is located on a level with the nominal water line in the boiler, there will be an error in the reading due to the head of water in the connecting tube. On large vertical boilers where the gage is brought down to within 6 or 7 ft. of the floor, this error becomes appreciable and should be corrected for in the calibration of the gage.

Fusible Plugs

Fusible plugs are safety devices placed in boilers to prevent damage from low water. They are usually placed at the highest point of the heating surface, or at that part of the heating surface which would first be uncovered if the water level was lowered.

In its simplest form a fusible plug consists of a brass or iron plug with a core made of some metal which has a comparatively low melting point. The plug usually has a thread cut on the outside so that it may be screwed into the heating surface of the boiler.

When installed in the boiler, the plug is normally covered with water, which keeps the temperature of the fusible metal below its melting point. Should the water in the boiler fall below the "low water" level, however, the fusible metal is melted by the heat of the furnace and the steam rushes into the furnace thus cooling down the fire.

Figure 6 shows two simple fusible plugs of the type described above, one of which is designed for inside insertion, and the other for outside insertion.

Another type is shown in Fig. 7. In this design, the inner plug D is made of copper and has a prolongation with a spherical end which practically closes the entrance, at the fire side, to the cavity beneath the plug. When the alloy is fused, the plug D is not blown right out into the fire but after dropping a certain distance is held suspended, while at the same time a free way is provided for the escaping steam. This is effected by means of a flange on the plug D and the ribs R on the interior of A. The hanging plug is then visible to the stoker when he is firing and warning is therefore given, even when the fire has just been lighted, that water is insufficient to cover the furnace crown.

Fusible plugs may be attached to a boiler directly or indirectly. Those described were of the direct type, since they were fitted directly into the shell of the boiler. In Figs. 8 and 9 are shown plugs of the indirect type. In this case, the fusible alloy is designed to melt at a much lower temperature than in the case of the direct type. Normally the plug is exposed to a temperature much lower than that of the steam, due to the comparatively stagnant water in the tube between the boiler and the plug. When the water level falls, the water drains out of the tube, thus exposing the fusible plug to the temperature of the steam, and causing it to melt. The escaping steam then gives warning either by blowing a whistle or by issuing as a jet.

Types and Details of Safety Valves

A Discussion of Types Together with a Description of Several Commercial Valves

SAFETY VALVES may be classified according to two general types, the weighted type and the spring-loaded type. The weighted-lever type, however, is more or less obsolete in this country and in many cases is prohibited by law.

There are a number of different forms of weight-loaded type valves, but all of them operate upon the principle that a certain dead weight holds the valve closed against boiler pressure. If the boiler pressure increases so that the total upward force of the steam against the bottom of the valve exceeds the weight holding the valve down, the valve opens and discharges steam. Two forms of weight-loaded valves are shown in Fig. 1.

In the spring-loaded type, the valve is held shut by the action of a spring. While this is an effective method, it has a disadvantage that, as the valve opens, the force exerted by the spring increases. This defect may, however, be made comparatively unimportant by using a long spring.

Springs used for loading safety valves may be used either in tension or in compression but most frequently are in compression. The locomotive type safety valve shown in Fig. 2 is of the tension type.

To be commercially practicable, the modern safety valve should be of the "pop" type, that is, it should pop open suddenly, without any previous leakage or simmering. In order to accomplish this, it is necessary to provide for a sudden, cumulative increase of lifting effort as soon as a small amount of steam leaks past the valve. This may be brought about in various ways. One is to design the valve so that, as soon as it lifts off its seat at all, the area of the valve against which the steam acts is automatically increased. Since the steam pressure per unit area remains practically constant during the opening interval, it is evident that the lifting effort increases directly as the area of the valve increases.

Another way is to allow the escaping steam to impinge on a portion of the disc in such a way that the impact of the jet produces an additional lifting effect. Again, the jet may be deflected downward by projections on the disk, thus producing an upward reaction. Most modern types of pop safety valves employ all three of these principles in combination.

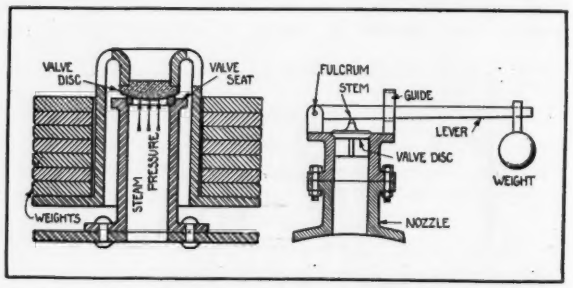


FIG. 1. TWO FORMS OF WEIGHT LOADED SAFETY VALVES

Pop safety valves are made with either exposed or enclosed spring, depending upon the type of service in which they are to be used. For low pressures and moderate temperatures, the springs may be enclosed, but for high pressures and where high-temperature, superheated steam is used, the spring must be fully exposed outside of the valve casing and protected from contact with the escaping steam.

Details of Makes

Safety valves are made in a great variety of styles and sizes by many manufacturers, and those described in these pages are only a few of the more typical makes.

In most cases, the manufacturers make other styles of safety valves in addition to the ones shown.

The American Pop Safety Valve

American pop safety valves which are made by the American Schaeffer and Budenberg Corporation are all

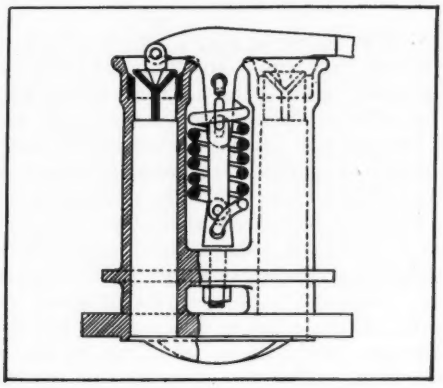


FIG. 2. LOCOMOTIVE SAFETY VALVE

the ring should be slightly raised, thus reducing the size of the opening between the lip of the valve proper and the edge of the ring.

Ashton Pop Safety Valves

These valves are made by the Ashton Valve Co. in both the open or exposed-spring style and in the enclosed-spring style, the former being designed primarily for use on high pressure and superheater service. A view of the enclosed-spring type is shown in Fig. 4. The screw plug pop regulator on the outside of the valve body affords a convenient means for regulating the pop at all times without taking the valve apart and with steam on the boiler. This regulator which is in the form of a hollow screw plug serves as a bleeder. It regulates the pressure in the main pop chamber by changing the area of the outlet passage into the discharge chamber. The screw plug is of composition and the screw threads do not come in contact with the escaping steam.

To change the set pressure on this valve, it is only necessary to remove the cap by loosening set screws and to adjust the screw. Turn the screw downward for increased pressure and upward for lowered pressure.

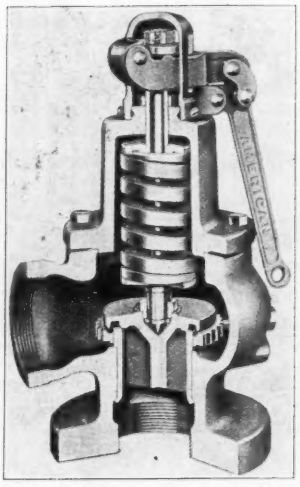


FIG. 3. MODEL "J" AMERICAN POP SAFETY VALVE

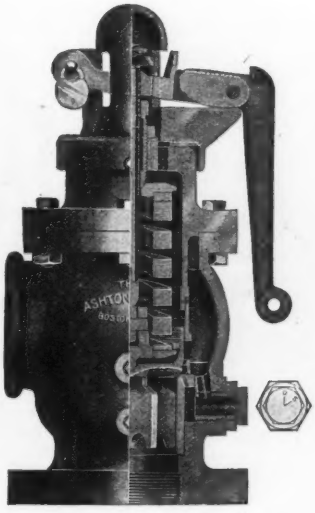


FIG. 4. ASHTON LOCKUP POP SAFETY VALVE

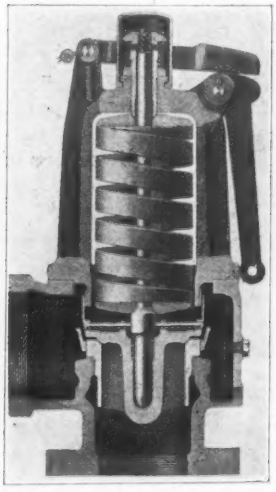


FIG. 5. SECTION THROUGH A CONSOLIDATED POP SAFETY VALVE

of the spring-loaded type. The model "J" valve shown in Fig. 3 has been designed to meet a wide variety of service and for pressures up to 250 lb. It is made with a body of cast iron, bronze mountings and malleable levers. A relief ring which fits over the upper part of the valve bushing serves to control the amount of blow back. The chamber formed by the relief ring and the overhanging lip of the valve proper is called the huddling chamber. The steam after coming through the valve is held in this chamber and escapes through the small opening between the edge of the ring and the lower outer edge of the valve lip proper, the size of this opening determining the amount of blow back, or difference between the opening and closing pressures of the valve when in operation. In reducing the opening pressure of a valve that has previously been adjusted,

The Consolidated Pop Safety Valve

In Fig. 5 is shown a sectional view of this safety valve made by Manning, Maxwell & Moore. This valve for both saturated and superheated steam has exposed springs. Steam passing the valve seat impinges on the flat outer ring of the disc and then passes upward through an annular orifice formed between the outer edge of the disc and the inner conical surface of the adjusting ring. Due to the conical shape of the surfaces, raising the ring restricts the discharge from the huddling chamber, increasing the pop lift and the blow down.

An interesting feature of this valve is the design of the seat. In any valve, the seat must retain its shape and trueness under all changes of temperatures and pressures, for the slightest amount of distortion from uneven

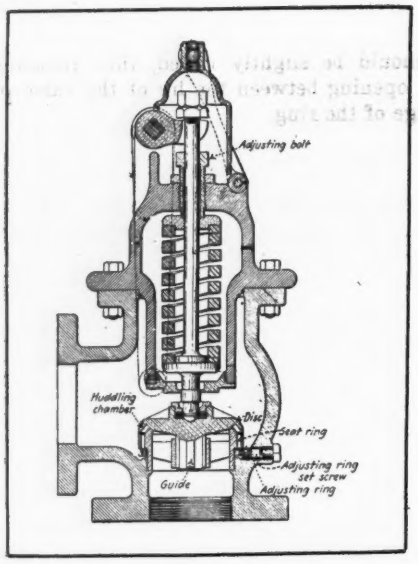


FIG. 7. CROSBY SAFETY VALVE

velocity of the escaping steam is no longer sufficient to sustain the disc against the tension of the spring, the valve closes instantly. The auxiliary device which closes slightly in advance of the main disc permits a steam cushion to form which allows the main disc to close tight.

Crosby Safety Valves

In the valve shown in Fig. 7, which is made by the Crosby Steam Gage and Valve Co., the popping pressure is increased by screwing down the spring-adjusting bolt to increase the spring compression, while the blow down is increased by raising the adjusting ring to the desired point, after which it is locked in place with a set screw. The operation of this valve is as follows: A slight increase in pressure above the point for which the valve is set starts leakage and a slight further increase permits enough steam to act on the outer area of the disc to force it up suddenly to its maximum opening. The sudden lifting effect is due to three causes: i. e., static pressure produced by huddling or partly confining the steam under the outer area of the disc, the impact of the jet upon the outer part of the disc, and

FIG. 6. TWO TYPES OF CRANE SAFETY VALVES

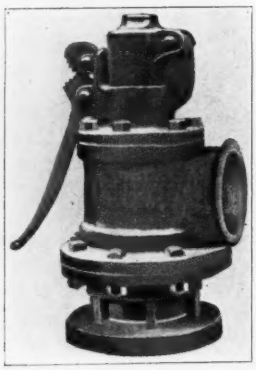


FIG. 8. LONERGAN PROTECTED SPRING POP SAFETY VALVE

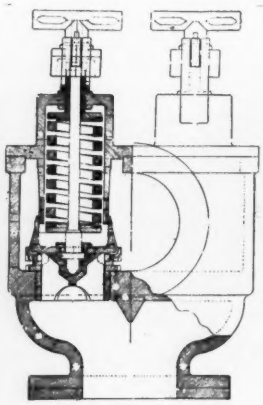


FIG. 9. CROSS SECTION OF LONERGAN VALVE

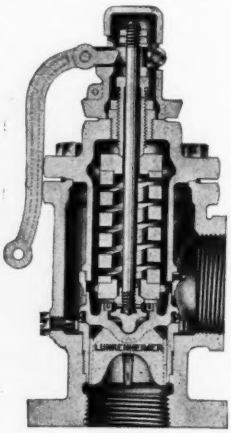


FIG. 10. LUNKENHEIMER POP SAFETY VALVE

heating will produce a leak. To prevent such an action in the Consolidated valve, its seat is raised above the base by an annular corrugated ring which absorbs or dissipates strains from uneven heating or external forces.

Crane Safety Valves

As may be noted from the illustration in Fig. 6, the valve made by Crane Co. makes use of an auxiliary spring and disc. This arrangement automatically regulates the blow-back of the valve within certain limits. The huddling or pop chamber of a Crane pop safety valve is so constructed that it is practically steam tight when the valve is closed. As a result, the slightest relief of steam past the seat immediately lifts the disc, thereby reducing the wiredrawing effect of the steam. To compensate for the restriction past the lip on the main disc, which ordinarily would result in a blow-back greater than is considered economical, the auxiliary device is provided with parts which relieve the pop chamber and furnish automatic control of conditions. When the the reaction of the jet forced downward again by the outer lip.

Lonergan Safety Valves

One of the distinguishing features of safety valves made by the J. E. Lonergan Co. is the double-eccentric lifting gear which makes it possible to lift the valve ⅛ of its diameter off its seat with no pressure under the valve. This feature may be noted in Fig. 8, which is a view of the model B protected-spring Lonergan pop safety valve. Details of the interior construction of Lonergan valves are shown in Fig. 9, which is a section through one of these duplex safety valves. The valve is made with flat seats and the blow-down is regulated by means of an adjusting ring which is accessible from the outside of the valve body.

Lunkenheimer Safety Valves

A pop safety valve of the enclosed spring type, made by the Lunkenheimer Co., is illustrated in Fig. 10. In this valve, the area presented to the escaping steam by the lip of the valve increases the lift. The action of the

lip can be adjusted without opening the valve, by removing the screw plug in the side of the body and inserting a rod to engage notches in the periphery of the adjusting ring. To increase the blow down, the ring is turned up—to decrease the blow down it is turned down. A change in the relieving pressure may readily be made by removing the cap at the top of the valve and adjusting the regulating screw—turning the latter down for a higher pressure and up for a lower pressure.

Although this valve is of the enclosed-spring type, it should be noted that the spring is completely protected from contact with the escaping steam.

Steam Outlet and Blowoff Valves

WHERE MORE THAN ONE BOILER SUPPLIES A COMMON STEAM LINE, NON-RETURN VALVES ARE ESSENTIAL

UNDER THE GENERAL term, Steam Outlet Valves, may be classified any type of valve used to control the steam output from the boiler. Valves used for this purpose may be either simple stop valves or may take the form of automatic non-return valves which permit steam to flow in one direction only. When two or more

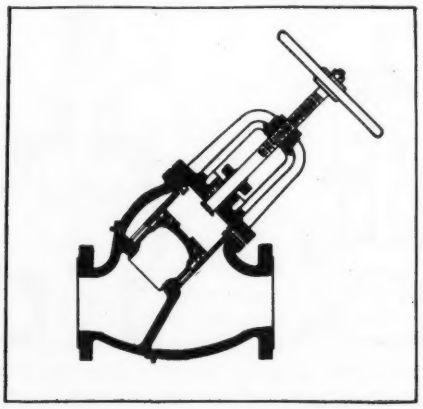


FIG. 1. CRANE Y PATTERN STOP CHECK VALVE

boilers are connected to a common steam main, two stop valves should be placed in the steam connection between each boiler and the steam main. The valves may be both of the outside screw and yoke type, or one may be an automatic non-return valve and the other a simple stop valve. When the latter combination is used, the automatic non-return valve should always be placed next to the boiler.

Non-return valves are used in this class of service because of their ability to equalize the pressure between the different boilers in the battery and to prevent the steam from one boiler passing through or into a boiler which has been damaged or which is not in use. In case a tube blows out, the valve closes automatically, owing to the reduction of pressure and prevents the header steam from entering the boiler. It acts also as a safety stop to prevent steam being turned into a cold boiler while men are working inside, because it cannot be opened when there is pressure on the header side only.

CRANE STOP CHECK VALVES

Crane Co. manufactures a number of different types of non-return valves for various kinds of service. The one shown in Fig. 1 is a view of the Crane Y pattern automatic stop-check valve. This valve will open promptly and automatically when the boiler to which it is connected reaches the full pressure in the main, but will remain closed against a higher pressure in the main; consequently, a sluggish boiler may be readily detected and the firing given proper attention. The valves are installed so that boiler pressure comes underneath the disc.

Another type of Crane non-return valve is shown in Fig. 2. The valve closes automatically to prevent steam from the header flowing into the boiler when an accident occurs to the latter, or, in case a rupture occurs in the steam mains, it will close to prevent the steam from the boiler flowing into the header.

When the valve has closed automatically, due to a break or sudden reduction in pressure beyond the out-

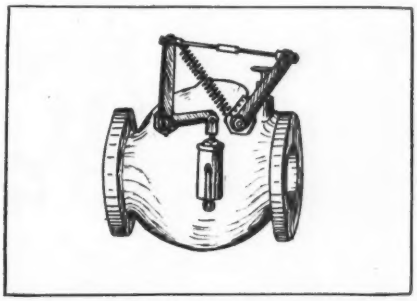


FIG. 2. CRANE HORIZONTAL AND EMERGENCY CUT-OUT VALVE

let of the valve, it will open automatically when the pressure in the header or main steam pipe again equals that of the boiler.

DAVIS CLASS C STOP AND CHECK VALVE

In the stop and check valve made by G. M. Davis Regulator Co., shown in Fig. 3, a departure is made from the usual custom, in that the dash-pot is located on the outside of the valve body, instead of inside the body. Scale formation, which is always a source of trouble in the operation of dash-pot valves, will have no effect upon the automatic operation of this valve. Oil is used in the dash-pot and effectively cushions the action of the disc, no matter how slight the movement. The valve is provided with an indicator in the form of a counterweighted lever used to balance the pressure acting on an area equal to that of the stem. This puts the valve in a condition of balance and insures its closure on a reverse flow of steam. The dash-pot, stem, and disc are all rigidly connected together and work in a vertical line. The dash-pot plunger is attached to the hand-wheel spindle and remains stationary.

ECLIPSE NON-RETURN VALVES

These valves are made by the Illinois Engineering Co. and, as may be noted from the illustration, have dash-pots to provide a cushioning effect when the valves

seat and to prevent chattering. The bronze dash-pot is independent of the iron valve body, thus avoiding strain from unequal expansion of the two metals. The valve is designed so that it can be packed while in service under pressure.

Edward Non-Return Stop and Check Valves

Edward non-return valves made by the Edward Valve and Manufacturing Co. are made with a closed dash-pot, which prevents any accumulation of grit and scale that might cause undue wear and sticking of operating parts. In any valve, the question of pressure drop is an important factor. In the Edward valve, the minimum cross-sectional area is at least equal to that of the corresponding pipe area. The dash-pot and piston construction used is highly effective in overcoming chattering and hammering. The built-up piston eliminates the valve triple acting. The valve serves as a protection either in case of failure of the boiler, or in case of an accident to the steam main. If a rupture occurs inside of the boiler, the reverse flow of steam acting immediately on the top of the valve disc, closes the valve automatically. If, on the other hand, a rupture occurs on the steam lines, the action of the pilot valve together with the double dash-pot arrangement manifests itself in closing the valve against boiler pressure, thus eliminating the havoc from such an accident caused by the boiler emptying its contents of steam. Ordinarily the pilot valve is set for about 8 lb. variation between boiler and header pressure, this supplying the differential on which the triple acting valve will operate in case of an accident beyond the valve. The pilot valve can be set for a less or greater differential by removing or adding lead shot or weight.

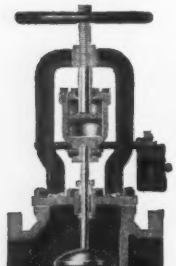


FIG. 3. DAVIS CLASS C STOP AND CHECK VALVE

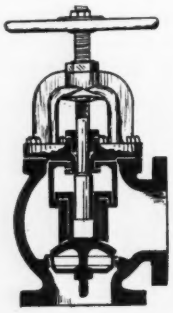


FIG. 4. THE ECLIPSE NON-RETURN VALVE

FIG. 5. GLOBE TYPE OF STOP AND CHECK VALVE MADE BY THE EDWARDS VALVE AND MFG. CO.

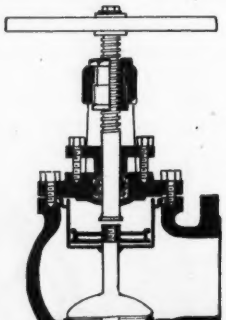


FIG. 8. JENKINS AUTOMATIC EQUALIZING STOP VALVE

the necessity of springing the piston rings over the piston, so that the ring is put into operation true to form and without strains.

Foster Automatic Non-Return Emergency Stop Valve

Figure 6 is a cross section through an emergency stop valve made by the Foster Engineering Co. In addition to providing protection against a rupture in the boiler, it gives protection in case of an accident to the steam header beyond the valve. As an automatic non-return valve, it functions in the ordinary manner; steam acting in a reverse direction on top of the valve disc causes the valve to seat.

When used as an automatic and emergency stop valve, use is made of an internal pilot valve. Whenever, from rupture or other cause, the pressure in the main line falls abruptly, a corresponding drop is experienced upon a diaphragm in the pilot valve, which in turn causes full boiler pressure to act against piston P in the main valve. Since the area of this piston is greater than that of the main valve, the valve instantly closes, preventing the flow of steam in either direction.

Golden-Anderson Triple Acting Non-Return Valve

This valve, made by the Golden-Anderson Valve Specialty Co., is shown in Fig. 7. It consists of a disc valve to the stem of which is fitted a double dash-pot, serving the double purpose of providing a cushioning effect when the valve tends to close suddenly, and of making

Another feature of this valve is the test connection shown in the illustration. This small branch pipe connection can be run to the floor or any convenient points for automatically testing or closing the valve. By simply opening the small hand valve, releasing pressure between the dash-pots A and B, the triple acting valve will instantly close. By closing the small hand valve, the triple acting valve will immediately return to automatic position. This feature makes it possible to determine, at once, whether the triple acting valve is operative and avoids going on top of the boilers to test the valve by the hand wheel.

Jenkins Non-Return Valves

In Fig. 8 is shown a view of a Jenkins Automatic equalizing stop and check valve. This valve is cushioned, to prevent chattering, by an internal dash-pot made entirely of bronze which eliminates the danger of sticking through corrosion. The valve is designed to shut off automatically the flow of steam from the header to a boiler in case of accident, and also to equalize the pressure between the different boilers in a battery. As the valve can only be opened by the pressure in the boiler to which it is attached, it is impossible to turn steam accidentally into a boiler which is being cleaned.

Lagonda Double Acting Automatic Cutoff Boiler Valve

This valve, made by the Elliott Co., is a stop, non-return and triple duty valve. It serves as a non-return

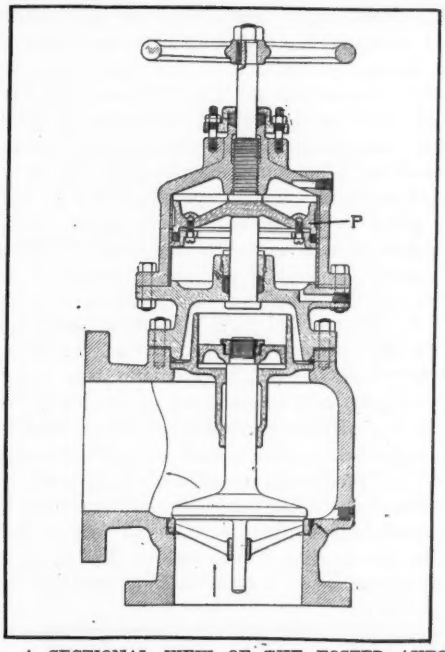


FIG. 6. A SECTIONAL VIEW OF THE FOSTER AUTOMATIC NON-RETURN STOP VALVE

and stop valve, and in addition will close when the flow from the boiler reaches a predetermined maximum. When acting as a check valve it acts in the same manner as a check valve. Referring to Fig. 8A, the normal flow in this type of valve is vertically upward, through the bottom flange, then outward, through the side opening. This makes a particularly handy form of valve for stop valve service, in connection with boilers. It will be noted that the normal direction of flow tends to close this valve. This tendency is, however, counterbalanced by the springs located within the dash-pot.

Lunkenheimer Non-Return Valves

Figure 9 illustrates a new type of safety non-return valve made by the Lunkenheimer Co. A feature of this

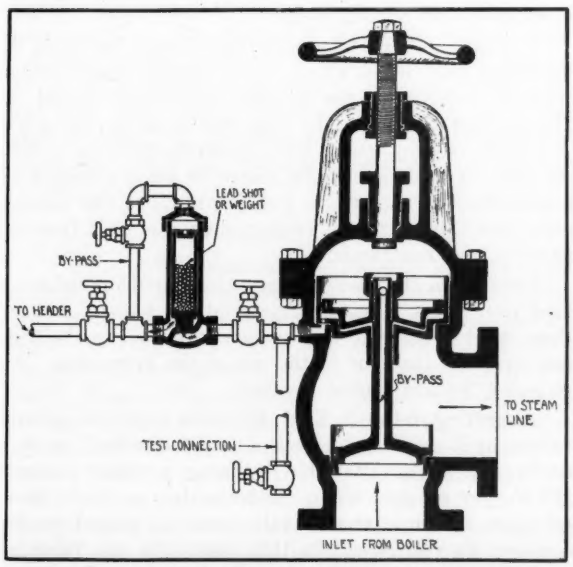


FIG. 7. GOLDEN-ANDERSON TRIPLE ACTING VALVE

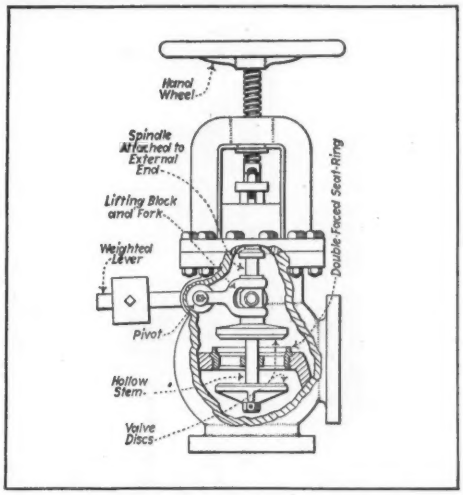


FIG. 8A. SECTIONAL VIEW OF LAGONDA TRIPLE DUTY VALVE

valve is that a spring is used to overcome the tendency to chatter, instead of the usual dash-pot arrangement. This spring is connected by a shaft and links to the disc which is accurately guided by the valve stem above the seat and a disc guide below. The spring is readily adjustable to meet individual plant requirements. With maximum tension on the spring, which condition would be necessitated only under extreme steam pulsations, the counterbalancing effect of the spring is less than one pound per square inch on the disc area. Another feature of importance from the operating standpoint is the ability of this valve to close, under banked fire conditions, when the valve stem is in a horizontal position. This is accomplished by reversing the balancing lever and spring, as shown in the small views, so that tension on the spring tends to close the valve.

Schutte and Koerting Non-Return Valves

Schutte and Koerting Co. has recently developed a series of non-return and emergency closing valves,

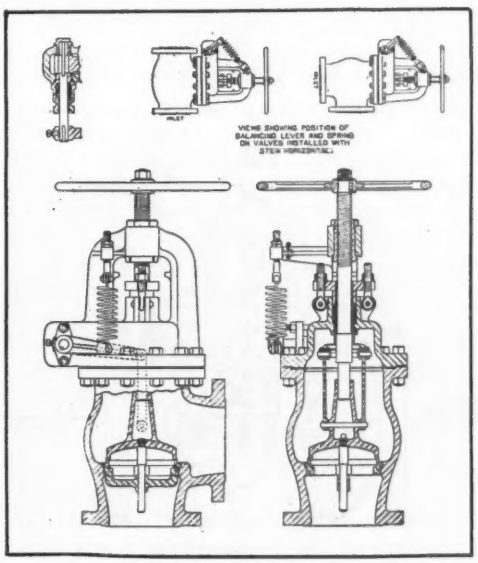


FIG. 9. SAFETY NON-RETURN VALVE OF THE LUNKENHEIMER CO.

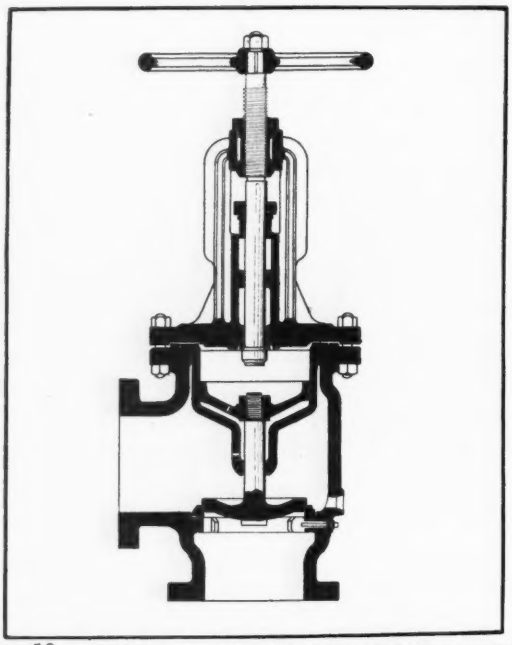


FIG. 10. SCHUTTE AND KOERTING NON-RETURN VALVE

one of which is illustrated in Fig. 10. These valves are designed for high pressures, up to 450 lb., and for temperatures as high as 750 deg. The valve shown is of the stop check type, with a piston at the upper part of the valve stem to prevent chattering. Fluctuation of pressure in the steam line causes a back lock against the disc of a valve, tending to drive it down to its seat. This back lock is absorbed in an upward direction by the piston which is approximately the same diameter as the disc, hence the blow is equalized in both directions irrespective of the position of the disc. A feature of these valves is the saw tooth thread on the seat ring. This construction permits lateral expansion and contraction without any raising effect, which, if present, would tend to produce leaks.

The Strong Non-Return Stop Valve

A view of the Strong Non-Return Stop Valve made by the Strong, Carlisle and Hammond Co. is shown in Fig. 11. The weight arm serves as an indicator to show the distance the valve is open and thus enables those in charge to locate the boilers not delivering the standard amount of steam. The valve is controlled from the outside, and the disc is held in balance by the weight. Slamming and chattering are prevented by an external spring cushion. The valve may be installed in either a horizontal, vertical or angle position, which is an advantage since by mounting a valve at an angle, it is often possible to reduce the total number of fittings.

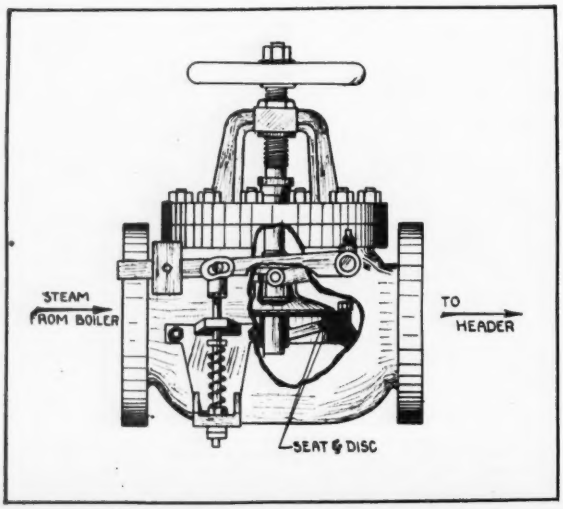


FIG. 11. STRONG NON-RETURN STOP VALVE

Blowoff Valves

Boilers are provided with blowoff apparatus so that a part or the entire water contents of the boiler may be discharged at the will of the operator. Apparatus for this purpose may be grouped conveniently into two classes, i. e., bottom blowoff equipment, and surface blowoff equipment. The bottom blowoff connection enables the operator to draw off the sludge and sediment which collects at the bottom of the boiler, while the surface blowoff is provided to skim off the scum which collects on the surface of the water. The surface blowoff usually consists of a skimming pan arranged to rest at the surface of the water by means of floats. The skimmer is connected through a flexible pipe to the external blowoff connection. Figure 12 shows a typical surface blowoff arrangement.

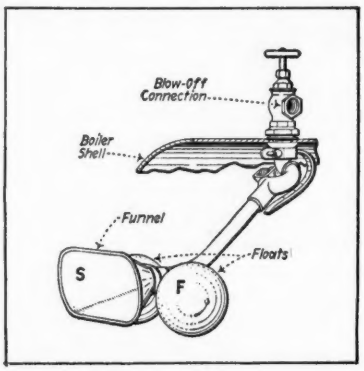


FIG. 12. TYPICAL SURFACE BLOWOFF ARRANGEMENT

The bottom blowoff connection should be made at the lowest part of the water space. All pipe and fittings used in making up the blowoff connection should be extra strong and should be protected from the hot gases of the furnace by means of a fire-brick wall, by a substantial cast-iron removable sleeve or by a covering of non-conducting material. The joint where the blowoff pipe passes through the setting should permit free expansion and contraction.

Fittings in the blowoff connection should be of steel. Cast iron is not a suitable material for blowoff connections, as it is liable to crack when subjected to the high temperatures incident to the use of the apparatus. No reducing fittings should be used.

According to the A. S. M. E. boiler code, two blowoff valves, or a valve and a cock must be installed on each boiler, when the allowable working pressure exceeds 125 lb. per sq. in. When the boiler has multiple blowoff pipes, a single master valve may be placed on the common blowoff pipe. In this case, only one valve on each individual blowoff is required.

Valves used for blowoff purposes should be specially designed and constructed for the purpose. Ordinary globe or gate valves are unsuitable and are not permitted, since they impede the passage of solid matter with the water which discharges from the boiler. A piece of scale or other foreign substance lodging between the disc and valve seat might make it impossible to close the valve when blowing down, and the consequence of such a condition would, of course, be emptying the boiler of its entire water contents in a short time. A blowoff valve must, for this reason, furnish a free passage for scale and sediment and must close and open easily without sticking.

Crane Blowoff Valves

In Fig. 13 is shown a view of a Crane Ferrosteel blowoff valve. Due to the nature of the service, blowoff valves are liable to be cut by scale, hence it is essential to have a valve which may be repaired quickly and cheaply. To prevent too frequent need of repairs, these valves are made with a removable, iron seat-ring having the seating surface on the outside of the ring. The disc is also made of iron and is arranged to form a

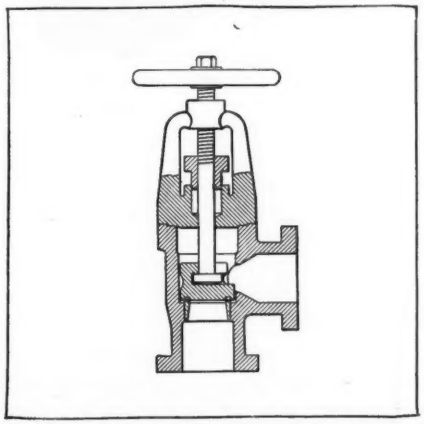


FIG. 13. CRANE FERROSTEEL BLOWOFF VALVE

throttling lip with the body, this construction being designed to prevent the scale from lodging between the seat and disc. The bonnet of the valves is easily taken off and the disc removed. These valves should always be installed so that the pressure will come on the top of the disc. They should also be opened wide when blowing off, so as to save the discs and seats from wear. These are important points as they affect the durability of the valve.

Lunkenheimer Blowoff Valves

Figure 14 illustrates a new cast steel monel mounted blowoff valve made by the Lunkenheimer Co. The seat ring is of monel, and is screwed into a monel bushing, which in turn is screwed into the body. The interposition of the bushing prevents corrosive action between the seat ring and body. The disc is of monel and is regrindable, reversible and renewable. The effects of wiredrawing and the consequent rapid erosion of the seating surfaces are minimized by the piston-shaped disc which, as the valve is closed, fits concentrically within the cylinder above the seat. The annular opening thus formed will not allow the passage of large particles of scale, but permits a thin sheet of water to be directed over the entire seat, effectively washing away any foreign matter which may have lodged upon its face. This pattern is available in sizes 2 in. and 2½ in.

The Everlasting Valve

This valve, as shown in Fig. 15, of the straight through blow-type, is made by the Scully Steel and Iron Co. It is made in different stock sizes for pressures up to 250 lb. and is made specially for pressures up to 400 lb.

It is arranged either single or in tandem. The tandem valve consists of two regular, Everlasting valves coupled together and both operated by one device. A hand wheel enables the valves to be operated slowly, the sequence of operation being always the same regardless of what the operator tries to do.

A sectional view of the single Everlasting valve is shown in Fig. 16. The seat is a long flat plate, which

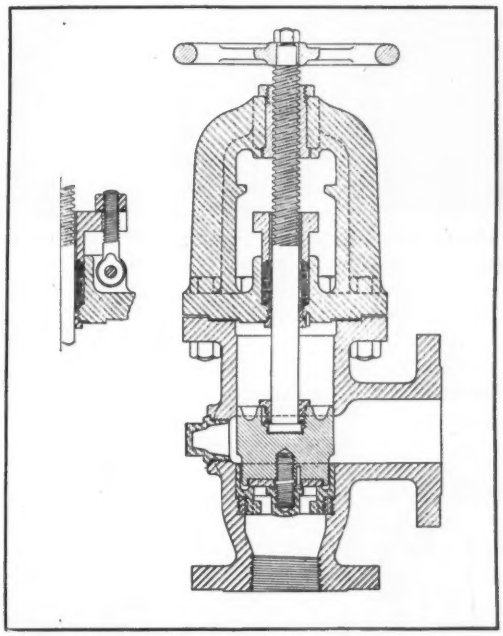


FIG. 14. CAST STEEL, MONEL MOUNTED BLOWOFF VALVE MADE BY THE LUNKENHEIMER CO.

the disc never leaves at any time. The disc is held to the seat by the pressure and by a stiff spring and, in traveling over the valve seat, has a slightly rotating movement, making it self grinding. Any grit or foreign matter deposited upon the valve seat is pushed aside or sheared off. The inlet orifice is tapered just above the seat, and is slightly less in diameter than the outlet, producing a nozzle effect which insures the delivery of water to the discharge pipe without wearing the seat as would be the case were this precaution not taken. It also has the effect of "syphoning" the valve clean at each operation.

"Ferrac" Blowoff Valves

These are made by the Edward Valve & Manufacturing Co., a sectional view of one of them being shown in Fig. 17. This valve has the Edward protected seat and disc which affords protection against the cutting action of the steam when the valve is partly open. Even when the valve is in the "cracked" position, the seating surfaces are widely separated and protected from

the direct flow of steam. The velocity of the steam across the seating surfaces is also greatly reduced.

Homestead Blowoff Valves

Homestead Valve Manufacturing Co. makes a blowoff arrangement consisting of a Homestead quarter-turn valve and a Hovalco blowoff valve in combination. Such a combination meets with the requirements of the A. S. M. E. boiler code, and has decided advantages; the Hovalco can be repaired or renewed at any time without closing down the boiler, by closing the Homestead valve, while the repairs are being made.

The quarter-turn valve, as its name implies, is so constructed that it opens and closes with a quarter turn. It is provided with a locking cam arrangement which holds the plug tightly to the seat at all times. Recently, a lubricated quarter turn valve has been introduced in which a lubricant is introduced to the wearing surfaces of the valve by a pressure system, such as the Alemite or Madican-Kipp oil systems.

In the Hovalco blowoff valve, the principal feature is the ease with which the seats or discs can be reground or replaced. The seat is held in position between the two sections of the body. When these two sections are loosened, the seat is automatically released and can be lifted from its place and reversed or renewed. A section through this valve is shown in Fig. 18.

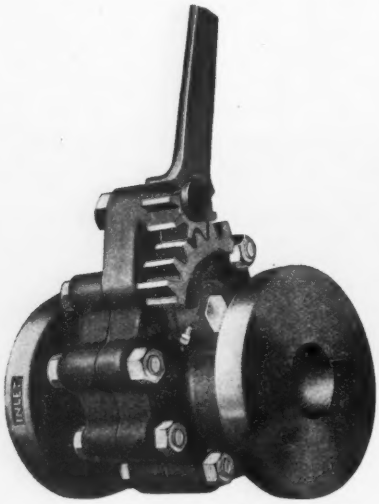


FIG. 15. THE "EVERLASTING" VALVE OF THE SCULLY STEEL AND IRON CO.

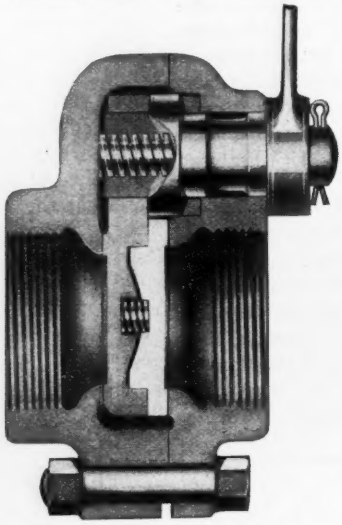


FIG. 16. A SECTIONAL VIEW OF THE EVERLASTING VALVE

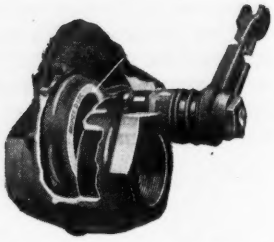


FIG. 20. THE OKADEE BLOWOFF VALVE

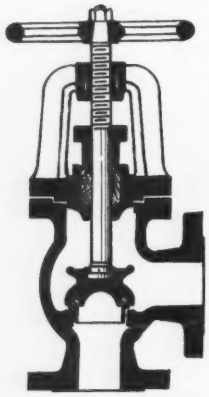


FIG. 17. "FERRAC" BLOWOFF VALVE OF THE EDWARD VALVE AND MANUFACTURING CO.

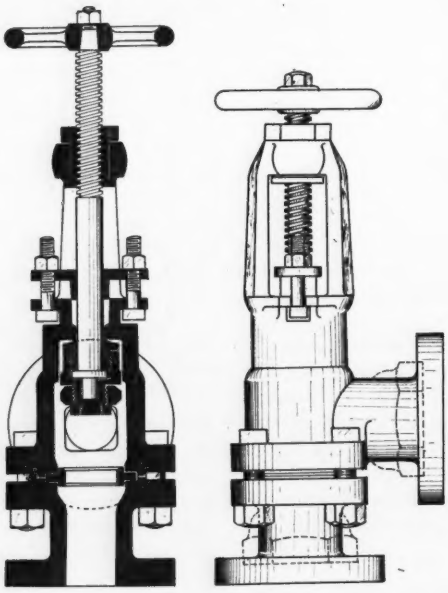


FIG. 18. HOMESTEAD VALVE MFG. CO.'S "HOVALCO" BLOWOFF VALVE

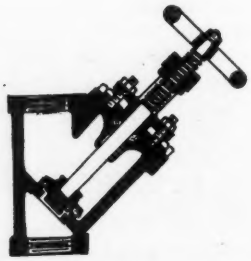


FIG. 19. JENKINS Y TYPE BLOWOFF VALVES

Jenkins Blowoff Valve

Figure 19 is a sectional view of a Y type of blowoff valve made by Jenkins Bros. This valve permits of a wide opening which offers practically no obstruction to

the free passage of foreign matter. When used in installations where the water is extremely bad, a strong plug cock placed between the valve and the boiler will keep mud and sediment away from the seat.

The Okadee Blowoff Valve

The valve shown in Fig. 20 is the Okadee of the Amco Sales Corporation. It is a straightway, quick-action valve, which while it may be used for other purposes, gives good service as a blowoff valve. It has no stuffing-box. A ring gasket on the inner end of the forged steel stem forms a joint with the inner end of the bronze steam bushing. The valve can be reground without detaching the valve body from the boiler by removing the large hexagon nut (which has the seat on the inner end) and the bronze disc. These parts may then be taken to the bench for retouching of surfaces.

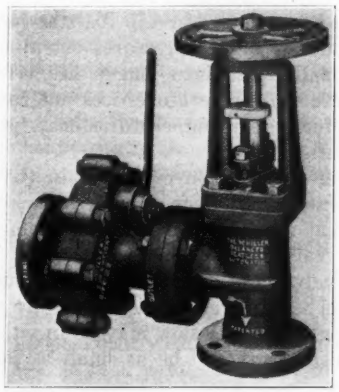


FIG. 21. SCHILLER COMBINATION EVERTIGHT AND SEATLESS BLOWOFF VALVES

Schiller Blowoff Valves

In Fig. 21 is shown a combination of two blowoff valves made by Joseph F. Schiller. This arrangement consists of a Schiller Ever-tight valve coupled directly to a Schiller balanced seatless blowoff valve. A view of the Ever-tight valve is shown in Fig. 21. This valve, as may be noted, is of the lever-operated type, in which a sliding member opens and closes the valve. The sliding member is so constructed that in passing from opening to closing position, the fluids and particles of solid matter blow through the sliding member as if it were a continuous pipe; they never come in contact with the seat. The sliding member is a geared rack of bronze and has inverted in it a loose valve disc of bronze with a spring between the sliding rack member and the valve disc. The only duty the spring performs is to keep the valve disc against the seat when there is no pressure. Holes through the sliding rack member allow the pressure to act on the flange of the valve disc, forcing it tight against the seat. This makes the valve tight and equalizes its pressure upon the seats, the valve being so balanced as to work easily under all conditions of pressure.

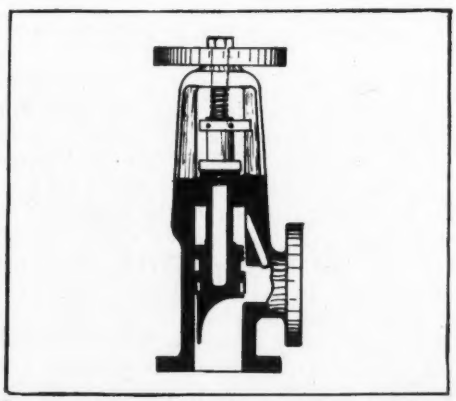


FIG. 22. SCHILLER BALANCED SEATLESS BLOWOFF VALVE

The Schiller balanced seatless blowoff valve which is the other half of the combination shown in Fig. 21 is of the piston type, so constructed that the piston is perfectly balanced and can, therefore, be manipulated easily. The valve is made in both the angle and the straightway type to suit various conditions. A sectional view of the seatless valve is shown in Fig. 22.

Hinged Door for Sidewalk Coal Holes

ASSOCIATED with sidewalk coal-holes are two types of hazards which are pointed out in The Travelers Standard as:—first, the serious danger of persons falling into the coal-hole while open and unguarded; second, the chance of persons slipping on the smooth metal cover or curbing of the opening and being badly hurt by the fall.

In nearly all cases, sidewalk coal-holes are circular, and when the holes are closed the disk-like covers are more or less securely fastened in place by means of hooks on the under side. Generally a chain is attached to the cover and also to the coal-hole curbing so that the cover cannot be carried any great distance away from the hole. This chain, however, does not prevent the absent-minded person from leaving the coal-hole open so that somebody may walk into it and be seriously hurt.

To overcome this danger, the Travelers Insurance Co. suggests the use of a hinged door arrangement, similar to that used in connection with sidewalk elevators, but of course much smaller. Such coal-holes could be made square, with either one or two doors, and each door, no matter how small it may be, should have at least two hinges. A single hinge is likely to become twisted and damaged so as to render it useless or ineffective. The hinges should not project above the walk, and in fact the entire cover and curbing should set flush with the surface of the sidewalk when the hole is closed. The coal hole should be so designed that the cover, or covers, cannot be opened much, if any, beyond the vertical position, and when in that position they should be held open by one, or possibly two, cross hooks.

Slipping of pedestrians on coal-hole covers can be prevented only by the use of some effective non-slip material; plain iron will not do, it must contain an abrasive.

KIND OF FUEL, depth of fire, method of firing and the rate of combustion are determining factors of draft loss through the fuel bed. The per cent of ash, fusibility of the ash and the air space through the grates are also factors. Only experiment will show their effects.

Boiler Piping Arrangements

Feed Water, Blowoff, Drip and Drain Safety Valve and Steam Piping

IN DESIGNING the feed water piping system for a boiler plant, the first thing to consider is the arrangement of the piping which with crossovers and bypasses will assure a means of conveying water to the boiler even though parts of the system may be out of service.

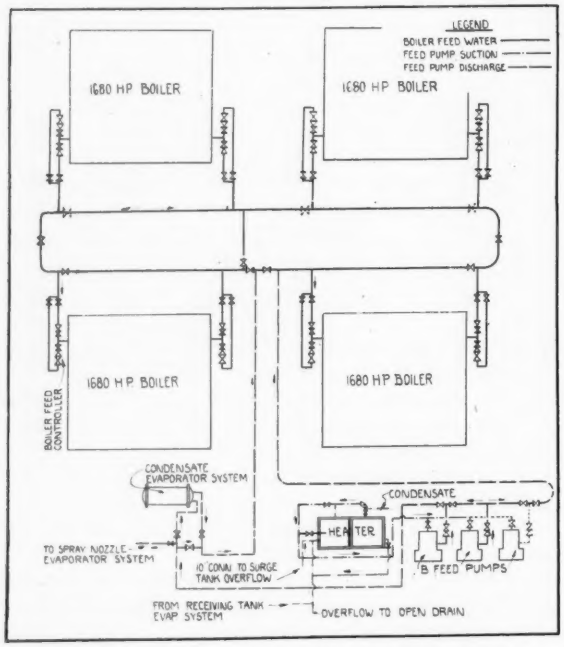


FIG. 1. LOOP OR RING SYSTEM OF FEED PIPING

The next point to consider is the size and strength of the mains and branches and the material of which it is made. Then comes the problem of selecting and locating valves and fittings and details of the connection to the boiler and the discharge arrangement.

Taking up the problem in the order mentioned, it is usual to arrange the main piping so that water may be fed to each boiler by at least two distinct methods. This may be accomplished in a number of ways; the two most common methods, however, are to employ either the ring system of piping with conveniently located crossovers, or the double-main system with separate leads to each boiler from each main. With the latter arrangement it is customary to use one main as the regular feed and the other as the auxiliary. Being used only in an emergency, it is not so essential that the auxiliary line be equipped as completely as the regular line; but with care in the arrangement of the piping the same feed water regulator, control valve and check valve can be used with either the regular or the auxiliary feed line.

An example of the ring or loop system is shown in Fig. 1, where it will be noted that only one crossover is needed for the battery of four boilers and each boiler has two distinct pipe connections to the main. In Fig. 2 is given an example of the double-main system of feed water piping where two pumps are used either one of which has sufficient capacity for the entire plant.

As to the size of feed water piping, common practice would indicate that the velocity in the pipe should range between 300 and 400 ft. a minute and it should be of such strength that it will withstand a pressure 50 per cent greater than that carried in the boiler. For working steam pressures not over 175 lb., standard iron pipe will serve, but for higher pressures extra heavy pipe is used, principally to insure longer life. Iron pipe is suitable where the temperature does not run above 200 deg. F., but for higher temperatures brass pipe has been used with satisfaction.

Regarding the location of valves in the feed water main, the general rule is to provide valves enough and so located that water may be shut off from any lead to a boiler by valves in the main; this may be done by alternating valves and lead connections around the loop. These should be gate valves, since they are always wide open or closed tight; the flow may be in either direction and the resistance should be as small as possible.

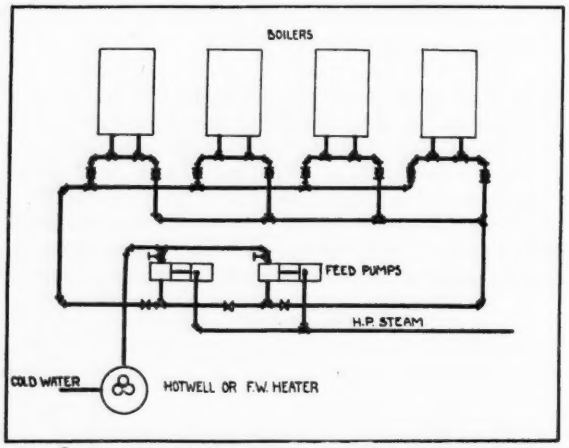


FIG. 2. DOUBLE-MAIN SYSTEM OF FEED WATER PIPING

In each lead from the main to the boiler, where hand regulation is depended upon, the most approved arrangement is to provide a gate valve, a regulating valve of the globe type, a check valve and second gate valve. During operation, the gate valves are kept wide open but by closing them either the regulating valve or the check valve may be repaired while the boiler is under pressure and the other boilers are being fed without interruption. In case a feed-water regulator is employed, it can take the place of the hand regulated valve; but, as it is more subject to failure than the hand-operated valve, a bypass should be provided around it with a hand-regulated valve to prevent a shutdown in case the regulator fails.

Where the feed pipe passes through the boiler shell or head of a drum, some form of bushing or threaded flange must be used, the lead-in pipe ending in the fitting at the shell and the internal pipe carrying the water from the fitting to the point of discharge. For return tubular boilers, the discharge pipe enters the boiler through the front head just above the tubes and extends 3/5 the length of the boiler before it discharges

above the center rows of tubes. By this arrangement the water is heated considerably above its temperature when passing through the boiler head. This internal pipe should be well supported above the tubes. In some cases the feed pipe discharges into a mud pan which gives further opportunity for the water to be heated and precipitate scale forming material before it mingles with the boiler water.

With water-tube boilers several arrangements are employed depending upon the type of boiler and the ideas of the designer. In all cases, however, it is general practice to discharge the water in the part of the water space where boiling is least violent and the A. S. M. E. Boiler Code specifies that the discharge should not be near a riveted joint or furnace sheet. Feed piping, particularly that within the boiler, is subject to internal deposit of scale and for this reason should be so arranged and provided with fittings that it can be easily cleaned.

Blowoff Piping

In order to allow for the proper removal of scum, precipitated scale forming materials and mud, every steam boiler is provided with one or more blowoff connections. These blowoff connections are of two general types, the surface blowoff, by means of which the scum

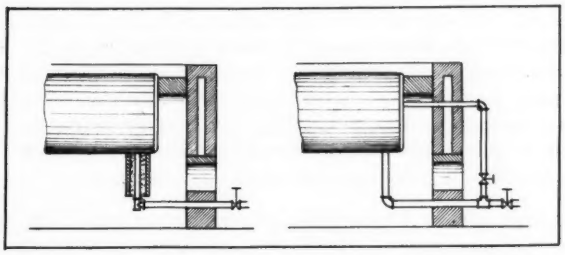


FIG. 3. METHODS OF PROTECTING BLOWOFF PIPING. (A) FIRE BRICK SLEEVE PROTECTION. (B) BLOWOFF CONNECTION WITH CIRCULATING PIPE

at the surface of the water is removed, and the bottom blowoff, by means of which the sludge and mud which collects at the bottom of the boiler is discharged.

Bottom blowoff connections are always made at the lowest part of the water space, and because of the severe service to which they are subjected are made extra heavy. Different methods are employed for protecting blowoff pipe wherever it is exposed to the fire in the combustion chamber. In most water tube boilers it is located well away from the hottest part of the fire so that it is only necessary here to consider the blowoff piping of a return tubular boiler.

Two common methods of arranging blowoff piping are shown in Fig. 3. In the first instance, the descending pipe is protected from the heat of the gases by a sleeve of fire brick, although a V-shaped pier of fire brick, with the point toward the front of the boiler, is sometimes employed. The horizontal pipe is bricked over or covered with a coil of plaited asbestos rope ½ to ¾ in. in diameter. Figure 3(b) shows the bottom blowoff pipe provided with a circulating pipe which enters the rear head of the boiler. Where the blowoff pipe passes through the rear wall of the setting, it should be surrounded by a sleeve, so that it will be free to move. To prevent air leaking in, the space between the sleeve and the pipe should be packed lightly with asbestos rope or a similar substance without interfering with the free movement of the pipe.

Diameters of blowoff pipes for fire tube boilers are commonly as follows: 1½-in. pipe for boilers up to 42 in. in diameter; 2-in. pipe for boilers up to 60 in. in diameter, and 2½-in. pipe for larger boilers. In low-pressure and water-tube boilers, the size of the blowoff is determined by the manufacturer, a tapped boss at the lowest point indicating the size of pipe to be used.

The Surface Blowoff

Surface blowoff piping should not exceed 1¼ in. in diameter. When inside and outside pipes are used they should form a continuous passage, but with clear-

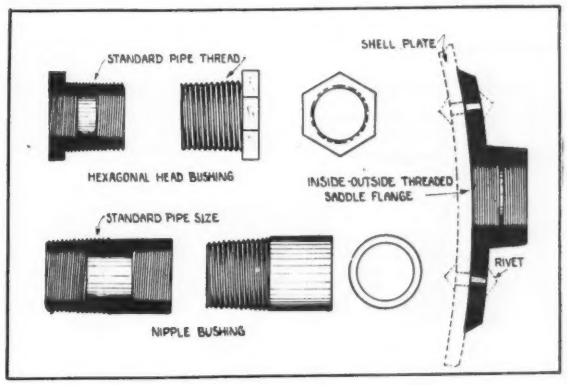


FIG. 4. BOILER BUSHINGS AND FLANGE

ance between their ends and arranged so that the removal of either will not disturb the other. A properly designed brass or steel bushing as shown in Fig. 4 must be used.

Bottom blowoff lines should never be less than 1 in. nor greater than 2 in. in diameter.

A smaller pipe may become clogged by scale. A larger pipe would cause a too-rapid loss of water.

Piping Arrangements

It is common practice to connect a number of boilers to one main blowoff header. Since only one boiler is blown down at a time, the diameter of this header may be only 3 or 4 in. All branches should connect to the header by means of a Y to minimize resistance due to mud, etc., and it is advisable to design the blowoff branch leading from the boiler to the header so that severe strains due to extreme expansion and contraction will not affect them. Short and rigid connections should be avoided and all possible flexibility introduced.

Blowoff Tanks

In most cities the local ordinances do not permit the discharge of blowoff water directly into the sewer. It is therefore usual to provide a steel blowoff tank, into which the water may be discharged and allowed to cool, before allowing it to drain into the sewer. In this way any damage which would result from discharging the hot water directly into the sewer is avoided.

The size of the blowoff tank depends upon the number of boilers to which it is connected. In some plants where a number of boilers are connected to one tank,

the tank may be from 5 to 6 ft. in diameter, and from 6 to 8 ft. in height. In smaller plants, a horizontal tank 3 ft. by 6 ft. is commonly used.

Such tanks should be provided with an overflow pipe and a vent. In designing a blowoff installation, the piping should be proportioned and arranged so that pressure within the tank cannot become excessive. Blow-off tanks, of course, are not made to withstand pressures and would explode if subjected to a considerable amount of pressure. It is for this reason that a vent pipe is provided. The vent pipe should be of greater area than the blowoff pipe inlet, and should vent directly to the atmosphere. The water connection to the sewer should also be of a size larger than the steam inlet to the tank.

Safety First Should Be Feature of Boiler Piping

ALL BOILER STEAM PIPING SHOULD BE LAID OUT WITH EXACTING CARE TO AVOID EXPANSION STRAINS

WHEREVER STEAM is supplied to either a reciprocating engine or a turbine, care should be taken to see that the steam reaches the units in as dry a condition as possible. If a slug of water ever finds its way to

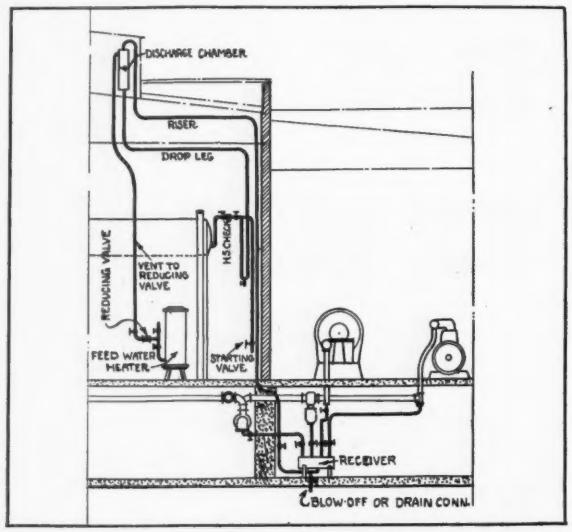


FIG. 1. HOLLY STEAM LOOP RETURNS CONDENSATION FROM STEAM LINES DIRECT TO BOILER

an engine, the results are liable to be fatal. To lessen the possibility of such an occurrence, good practice calls for the use of a separating chamber immediately ahead of the throttle valve. To be effective this apparatus must, of course, be kept well drained.

All steam piping should be so arranged as to be free from pockets where water of condensation might collect and it should in addition, have a slight pitch in the direction in which the steam is to flow. In this way, condensation, which will collect along the bottom of the pipe in spite of the best insulation or high superheat, flows along with the steam and has no tendency to back up against the flow in such a way that a slug is likely to be formed.

Where pockets are unavoidable and at intervals along the pipe, suitable drain pipes should be provided to carry off the water of condensation as it collects. This condensate represents too many heat units to be thrown away, hence all drains should be piped to a receiver from which the hot water may be trapped or pumped to the feed-water heater or back to the boiler.

Where it is desired to return these returns direct to the boiler, a steam loop may be employed to advantage. For small installations, a simple loop may be used but where there are many points requiring drainage, the Holly loop is better suited. Such a system is shown in Fig. 1. All condensation gravitates to a receiver and then passes to the riser. The receiver is placed below the lowest point to be drained serving as a storage for large or unusual quantities of water and enabling the riser to function at a constant rate independent of variable discharge into the receiver. The comparatively low pressure required in the discharge chamber, located above the boilers, to secure the lifting of the mixture of water and steam through the riser is produced by a reducing valve discharging into the feed-water heater.

Circulation is set up by opening the starting valve until steam appears; this valve is then closed and the reducing valve is put into operation. Condensation is forced from the receiver into the riser in the form of a spray which is produced by holes drilled in the riser connection in the receiver. From the riser the spray enters the discharge chamber where the water and steam are separated. The water drops by gravity into a drop leg, thence to the boiler. The steam discharges through the reducing valve to the feed-water heater.

SAFETY VALVE PIPING SHOULD BE SHORT AND DIRECT

Safety valves should be installed directly on the boiler safety valve nozzles wherever possible. Where this arrangement is not feasible or convenient, a short section of pipe may be interposed. Such intervening pipe or fitting should be no longer than the face to face dimension of the American extra-heavy iron flanged tee fitting of corresponding size. This pipe should have the same area as the boiler nozzle and should contain no valves. Where more than one safety valve is used on a single nozzle, a manifold is necessary. The branch sizes are determined by the sizes of the valves, and the area of the base should be at least equal to the sum of the areas of the branch connections.

Safety valves should preferably discharge direct to atmosphere; i.e., without any discharge pipe, as this construction precludes the possibility of back pressure. To prevent the escape of steam into the boiler room, however, as a safety measure for anyone working over the boilers, it is sometimes desirable to use a safety-valve discharge line to conduct the steam out into the open. In this connection the A. S. M. E. boiler code requires that all safety-valve discharges shall be so located or piped as to carry clear of running boards or platforms. Where such a discharge pipe is employed, the cross-sectional area should be not less than the full area of the outlet valve or the total of the areas of all valves discharging into it. The pipe should be as short and as straight as possible and so arranged as to relieve the valve body of unnecessary stresses. No valves are permitted in the discharge line just as is the case on the pressure side of

the valve. Ample provision should be made for gravity drain at or near each safety valve where water of condensation may collect.

Boiler Steam Leads

In making up specifications for steam leads from the boiler to the main header, a number of factors must be given consideration, if satisfactory results are to be obtained. Among these are the size necessary to give the allowable steam velocities; the weight and material necessary to withstand the pressure carried; use of bends to relieve expansion strains; insulation; pitch; and some other items of less importance.

The question of what steam velocities will be permissible depends largely upon the condition of the steam and what use is to be made of it. In general, where the flow is steady as for supplying turbines higher velocity may be allowed than when the flow is of a pulsating nature, as is the case when the steam is supplied for reciprocating engines. When superheat is used, the velocity may be higher than for saturated steam; also the allowable velocity may be increased as the pressure increases. In the final analysis, the problem becomes that of balancing the yearly loss due to friction and radiation against the interest on the investment in the piping, to secure the least ultimate annual cost. In practice, velocities of the order of 15,000 ft. per min. are suitable for high-pressure superheated steam for turbine service. With pressure below say 150 lb. per sq. in., where no superheat is employed and for reciprocating service, maximum steam velocities should not exceed about 9000 ft. per min. These figures are for normal operation which may mean any maintained boiler rating; when peak loads occur, these figures will, of course, be exceeded.

Having fixed the velocity desired in the piping, consequently the inside area and diameter, it is necessary to determine the wall thickness required to withstand the pressure carried. A factor also to be taken into consideration here is the material from which the pipe is made. Good practice dictates that cast iron be not used for steam pressure piping hence this material is eliminated. Wrought iron, having an average tensile strength of about 50,000 lb. is sometimes used, though not frequently. Mild or low carbon wrought steel is almost universally used for steam pressure piping. It has the necessary ductility and an average tensile strength of about 65,000 lb. per sq. in.

Pipes carrying either saturated or superheated steam may be either welded seam or seamless wrought-iron or steel stock; steel pipe in sizes over 3 in. should be made from open hearth stock. Sizes up to 3 in. may be either lap- or butt-welded but, for larger sizes, lap-welding should be employed. For pressures not exceeding 200 lb. and superheat not exceeding 200 deg. F. full weight steel is usually specified for sizes up to 12 in. diameter. Above this diameter a thickness not less than $\frac{3}{8}$ in. is required. For pressures and temperatures above those mentioned, extra heavy stock should be used.

The A. S. M. E. boiler code specifies that in determining the thickness to be used for pipes at different pressures and for temperatures not exceeding 700 deg. F., the following formulas are to be used:

For pipes having nominal diameters of from $\frac{1}{4}$ in. to 5 in.,

$$P = (2S \div D)(t - 0.065) - 125$$

and for pipes of nominal diameter over 5 in.,

$$P = (2S \div D)(t - 0.1)$$

where P is the working pressures in lb. per sq. in. gage; t, the thickness of wall in inches; D, the outside diameter in inches, and S, the allowable fibre stress, which may be taken as 9000 lb. per sq. in. for seamless steel pipe, 7000 lb. per sq. in. for lap-welded steel pipe, 5000 lb. per sq. in. for butt-welded steel pipe, 5300 lb. per sq. in. for lap-welded wrought iron, and 4500 lb. per sq. in. for butt-welded wrought iron.

When the temperature of the steam exceeds 700 deg. F., the allowable stress should be reduced.

Connection between the boiler and header should be so arranged that it will be self draining and that expansion strains will be taken care of. Pockets should be avoided by the proper location of the automatic stop and gate valves. Placing all valves in the horizontal run eliminates pockets and is therefore approved practice although other arrangements are used, provided, of course, with adequate drains as shown in Fig. 2. Long

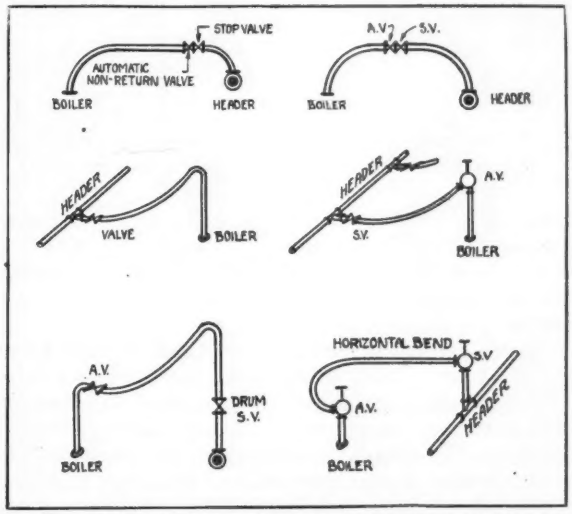


FIG. 2. BOILER LEADS SHOULD CONTAIN LONG RADIUS EXPANSION BENDS AND SHOULD ALLOW FOR FREE EXPANSION IN THREE DIRECTIONS

radius bends should be used wherever practicable to reduce friction and to take care of expansion strains. In order to avoid the necessity of springing bends into position, due to slight inaccuracies of construction, triple swing connections should be used. A form of construction having one horizontal and two vertical joints at one end of the connection accomplishes the desired results, permitting of a swinging adjustment in three places. The joint face at the other end of the connection should be so located that the centerline of the joint will not coincide with that of any of the three joints mentioned.

When a number of boilers are served by one breeching a great deal of draft trouble may develop unless the boiler dampers are all equalized to the same draft. To accomplish this all the fires should be brought to the same condition as to thickness and freedom of holes and thin spots. Each damper can then be adjusted to the standard draft and thereafter the main damper at the stack need be the only one regulated to take care of the changes in load condition.

Practical Ways of Obtaining Boiler Economy

FUEL WASTE CANNOT BE ATTRIBUTED TO ANY ONE OUTSTANDING CAUSE, BUT RATHER TO A GREAT MANY EASILY OVERLOOKED DETAILS OF OPERATION

PROPER DESIGN and careful construction of boiler furnaces will contribute to economy only so far as the operator is willing to avail himself of and put into practice proved methods of operation. A new setting, or one to which extensive repairs have been made, can be greatly damaged by not properly drying out the new

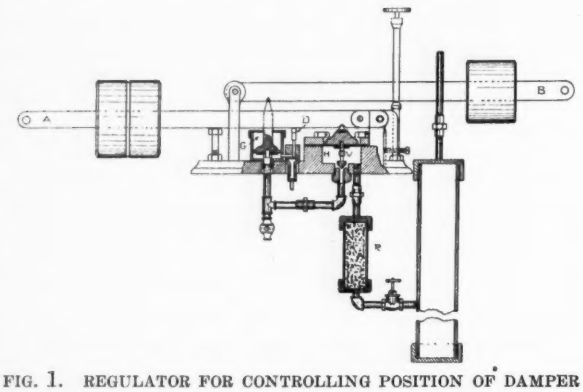


FIG. 1. REGULATOR FOR CONTROLLING POSITION OF DAMPER IN ACCORDANCE WITH CHANGES IN STEAM PRESSURE

brick work. Drying should be accomplished by running a slow wood fire, with water in the boiler, for from two to five or six days. The more time taken for drying, the less trouble will be experienced during later operation.

Three general methods are practiced in hand firing power boilers. First, firing large quantities of fuel at long intervals. This method is mentioned only because it is absolutely wrong, yet is used by many indifferent firemen. The second method is that of spreading four or five scoops of coal over one-half the grate and then waiting one firing period before firing an equal amount by the same method on the other half. With high-volatile coals it will be necessary to crack the fire door open for a few minutes after firing in order to furnish sufficient air for smokeless combustion. This method is probably the one most generally used because the fire doors are kept open but for short periods, it is easy for the fireman to spot quickly holes or clinker and the fuel bed is not disturbed, which is an important item with clinkering coals.

In the third or coking method of firing, the coke is cleared from the front third of the grate by pushing it back evenly over the back two-thirds. A large quantity of fresh coal is then fired on the front end. Gas will be distilled from the fresh charge and be consumed as it passes over the incandescent coke bed. With this method it is difficult to keep holes from burning through the coke bed.

Hand firing is hard work and it is easy, as a rule, to convince a fireman that, by proper methods, he can save coal and also muscular effort and time. It is important that he should fire often and light, keep the fuel bed even and not too heavy, prevent holes developing in the fire and regulate the draft by the stack damper in accordance with the load. Ash pit doors are not to be used for regulating draft, but the fireman should not hesitate to admit air above the fire during the period just following the fresh fuel charge.

DO NOT WORK ASH INTO HOT ZONE

Burning bituminous slack is often difficult as it cakes over or the ash may fuse; in either case, air will be greatly retarded in passing through the grate and

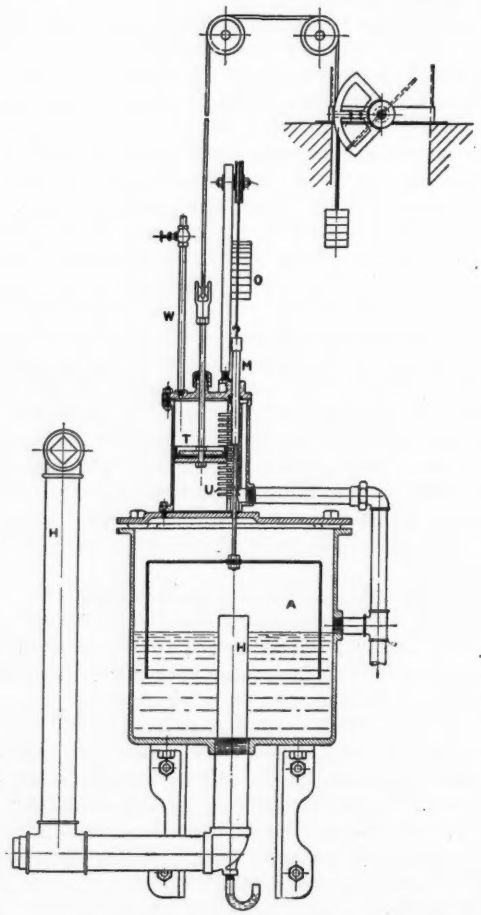


FIG. 2. CHANGES IN DRAFT OVER FIRE CAUSE VARIATIONS IN POSITION OF WATER-OPERATED PISTON THUS OPERATING DAMPER

fuel bed. To break up the fuel bed, run the slice bar in on top of the grate and turn or lift it just enough to loosen the cake or clinker. Do not break clear through the bed because, by so doing, ash and clinker will be worked up into the hot zone and the clinker condition made worse.

At certain periods during each shift the fuel bed will have thickened up so that it must be cleaned, if evaporation is to be maintained. A satisfactory way to do this is to clean one side of the grate at a time. Push all coke to the rear of the grate and clean the clinker from the front half. Then pull the coke to the front and clean the rear half by pulling the clinker out over the coke. Some firemen prefer pushing the coke to one

side and cleaning one-half the grate opposite each fire door from front to rear. In any event, the fire should not be burned so low but that there is sufficient coke left to spread over the grate and thus form a bed to prevent the new fuel falling through the grates. After half of the grate has been cleaned and the fire is burning briskly, the other side may be cleaned.

Anthracite should be fired evenly, in small quantities and at short intervals. Fire tools should be used as little as possible and care must be taken in cleaning owing to the difficulty of igniting the fresh charge.

Maintain an Even Fuel Bed

Mechanical stokers fall into three general classifications: chain-grate, overfeed and underfeed. In chain-grate stoker operation, if the fire pulls away from the gate, it will be necessary to decrease the speed, thicken the fuel bed or adjust the dampers. It is generally better to run a thick fire slowly, than it is to run a thin fire fast. The average speed will be from 3 to 4 in. per min. If the fire tends to pass over into the ash pit, the fuel bed is traveling too fast or is too thick for the draft or load. The fuel should just be consumed as it reaches the rear turning point. An uneven fire may be caused by stratification of coal sizes, improper preparation of a new fire, a failure of a part of the ignition arch, an obstruction at the stoker gate, or clinker adhesion to the side walls.

Operation of overfeed stokers may result in trouble from ash fusion along the side walls and at the bridge wall. This can be prevented by slicing the fires and dumping the ash before it fuses. Grates should be kept covered with fuel, the thickness to be determined by the load.

With underfeed stokers, great care must be taken not to get too hot a fire on the ash plate. With some coals it is necessary to pour a little kerosene in the plunger cylinders to cut the caked coal dust. Always keep plenty of fuel over the grates and keep the fuel bed uniform and as clinker-free as possible. With most bituminous coals, 18 to 24 in. of fuel over the grates will give good results. The greatest depth and hottest part of the fire should be over the retorts. If the fuel bed gets too thick, slow up the stoker. The moving parts of all mechanical stokers should be well lubricated.

Fuel oil must be introduced into the furnace in a thoroughly atomized state; then it must be intimately mixed with the proper amount of air so as to complete its combustion before the gas strikes the boiler heating surface. Burners must be kept clean. A dazzling white flame may indicate an excess of air. With too little air, no violet is seen in the flame, the red darkness and smoke appears. Burner vibration can be stopped by increasing the air supply and velocity, or by cutting down on the oil supplied to the troublesome burner.

Draft Control

In the operation of a boiler furnace, air for combustion may be drawn into the furnace by a difference in pressure between the atmosphere and the interior of the furnace, caused either by the heated gases in the stack or an induced draft fan; or it may be forced into the furnace by a fan which creates an air pressure under the fuel bed, the gases being drawn from the furnace by stack or induced draft. As there are three methods of supplying air, there are also three points of control; i.e., the stack damper, speed of induced draft fan and the air pressure in the windbox.

In all cases, the amount of air supplied must be in proportion to the fuel burned. For economical combustion the amount of fuel burned cannot be controlled by the air supply alone; in other words, with a given amount of fuel in the furnace, at or above the kindling temperature, a definite amount of air must be supplied or combustion will be incomplete. Every sudden change in air supply causes a momentary reduction in efficiency; either unburned gases escape up the stack or too much air must be heated to furnace temperature. Control of the air supply to the furnace is, however, the most sensitive method of adjusting furnace temperature to suit rapid changes in load conditions and it is therefore,

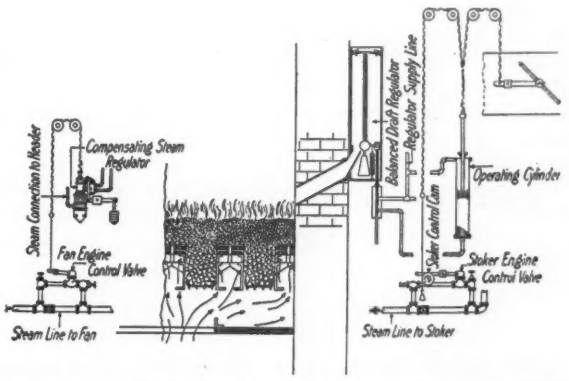


FIG. 3. DIAGRAM OF EQUIPMENT FOR CONTROLLING DAMPER POSITION, FAN AND STOKER ENGINE SPEEDS

always used in boiler operation, though usually supplemented by means for controlling the rate of fuel feed.

With other conditions remaining constant, changes in the load carried by a boiler will be indicated by the steam pressure gage, the pressure going up with decrease in load and vice-versa. Changes in load conditions must be met by changes in the rate of combustion, so that the usual method is to secure changes in the adjustment of air supply and fuel feed in accordance with the changes in steam pressure.

In the completely manually operated plant, draft is controlled by opening and closing the damper in the breeching of each boiler, according to steam pressure changes as indicated by the pressure gage. Where an induced draft fan is installed to serve a battery of boilers, the variations in the load on the plant are cared for by changes in the speed of the fan, the individual boiler dampers being used to distribute the load among the boilers. In either case the ashpit door should be left wide open as any attempt to control draft by this means will cause air to leak through holes in the setting and result in unnecessary losses. Automatic damper regulators have been developed which change their position with change in steam pressure. These have a great advantage over the manually-operated damper, as they will maintain the pressure practically constant, but they do not proportion air to fuel feed thus leaving to the operator the problem of securing economy.

Where forced draft is employed, it is usual to control by means of steam pressure variations, in addition to the

stack damper position, the speed of the fan, or, where several furnaces are supplied by one fan, the position of the butterfly damper between the air duct and the windbox.

By extending the automatic control to the rate of feeding the fuel, as may be done with stoker-fired boilers, combustion may be maintained uniformly high in efficiency, since the speed of the fan and the stoker may be changed in unison thus giving a correct proportion at all times, regardless of the load carried. Where complete automatic control is employed, the general practice is to vary the rate of fuel feed and amount of forced draft in proportion to the load carried as reflected by variations in steam pressure. Then, to secure the removal of the furnace gases at the proper rate, some mechanism is provided for adjusting the damper or induced draft fan speed so as to maintain constant draft over the fuel bed in the furnace. Where complete automatic control and forced draft are employed the draft over the fire should be very low, just sufficient to carry the gases away and prevent leakage of gases to the atmosphere. Where forced draft is not employed, the draft over the fire must be sufficient to give the required rate of combustion.

Feeding and Blowing Down Boilers

Two Factors in Boiler Operation Which Are Highly Important as a Means of Maintaining Proper Water Level in the Boiler

NO FEATURE of boiler operation is more important than that of maintaining proper water level in the boiler. If too high, water will be carried over with the steam to the superheater or steam-driven equipment. With water too low, tubes or shells become overheated, weakening the metal to the point of causing an explosion. Although promiscuous fluctuation of the water level is uneconomical and frequently dangerous, an unvariable water level is not the most economical condition, except where the load carried is constant.

Modern practice favors a variation in water level with the load being carried; as the load carried by the boiler increases, the water level lowers; thus, by the slight decrease in steam pressure, due to the increased demand for steam, some of the boiler water is permitted to flash into steam without completely replacing it with feed water until the furnace conditions have had an opportunity to adjust themselves to the new load. With a decrease in load, the rate of feeding is not adjusted immediately to the steam output of the boiler, which permits a rise in water level and the storing of heat in the boiler water which may be called upon in case of a sudden demand for steam. The fluctuation is, of course, always within safe limits of operation.

Such conditions cannot be maintained by hand regulation as the adjustments are too delicate and require too close attention, particularly where the load is of a variable character; the action can, however, be approximated, even with hand regulation. The operator's guide in maintaining water level is the gage glass supplemented by occasional use of the trycocks on the water column. The column should also be equipped with high and low alarms, particularly when hand regulation is depended upon.

In the case of fluctuating loads, a sudden demand for more steam causes more violent ebullition, so that the boiler water contains more steam bubbles, consequently its volume increases and, without any change in the rate of feeding, the water level rises. With a decrease in load, the reverse takes place. Hence any automatic rgulator which varies the rate of feeding according to the level of the water in the boiler will give opportunity for the furnace conditions to be adjusted to changed load conditions before changing, materially, the amount of water being fed into the boiler. This results in higher economy than would otherwise be the case, as changes in furnace conditions cannot be made rapidly without losses due to improper combustion conditions during the time the changes are taking place.

Three general types of feed water regulators are employed to accomplish the results of continuous feed and delayed changes in adjustment with sudden changes in load upon the boiler. One employs an inclined tube placed at the working level of the water. The varying level of the water in the tube, one end of which is connected to the steam space and the other to the water space of the boiler, changes the length of the tube, which movement is communicated through levers to the control valve.

Another type of regulator also works on the thermostatic principle but in this case the inclined tube is surrounded by a jacket containing a readily volatilized liquid. Changes in the water level cause more or less of the liquid to volatilize with resultant changes in pressure within the jacket. By means of tubing, this change in pressure is communicated to the control valve which governs the flow of feed water to the boiler.

In the third type a float with lever attachment is the actuating device. This is inclosed in a chamber which is in communication with the steam and water spaces of the boiler and its movement, accompanying changes in water level, causes variations in the opening of the feed-water control valve.

In all cases it is essential to maintain a pressure in the feed lines above that in the boiler; 10 to 20 lb. is usually considered sufficient, although in some cases as high as 50 lb. difference is maintained. With the higher difference in pressure, however, difficulty is experienced in keeping the seat and disc of the control valve in good working condition.

As regards the location of the controlling element of a feed-water regulator, it is essential that the water level in all parts of the boiler be within the safe working limits at all times and, as is well known, many types of boilers, particularly of large size, are subject to varying water level in different parts of the boiler. In such instances, it is customary to equip the boiler with two feed-water regulators placed on opposite sides of the boiler.

Blowing-off Boilers

While no hard and fast rules can be laid down in regard to the number of times a day a boiler should be blown down, it is safe to say that it should be done at least once every twenty-four hours. If the boiler is banked over night, it should be blown down before starting up in the morning. If the boiler is operated continuously, it should be blown when it is being operated at a relatively low rating and when the circulation is not rapid. Perhaps the best way in this case is to blow after cleaning fires.

When surface blow cocks are used they should be opened often but only for a few minutes at a time. Opening and closing a blowoff valve should be done slowly and cautiously; yanking the blowoff valve open or closed is dangerous, and this applies not alone to blowoff valves but also to every valve in the steam plant.

Insufficient blowing down is indicated by the existence of foaming, priming or scale formation. In some plants a sample of the water in the boiler is tested at frequent intervals, to determine the amount of foreign matter present. If the test indicates a high concentration, the boiler is blown down a certain amount, the amount of blow down necessary having been determined by previous experiment. This is obviously the most scientific way of blowing down boilers, and in plants where it has been tried out has been entirely successful. Frequent blowing down of boilers results in a great loss of heat units, and the number of blow downs per day must be kept as low as possible, without endangering the boiler or impairing operation.

In any case, boilers must not be blown down until the sludge and foreign matter in the boiler has been given time to settle. A blow down during the steaming period will rid the boiler of only that sludge which happened to be in the lower tubes at that time.

Proper care must be taken not to blow down to a dangerous level. In water tube boilers an element of danger is sometimes present on account of the relatively large blowoff pipe, small drum and high steam pressure. With such a combination it is possible that even with quick operation of the blowoff valves the attendant would have great difficulty in properly blowing down without leaving the drum at all certain of the tubes empty and exposed to the hot gases. In some cases, this time has been found to be as short at 8 or 10 sec.

Keeping the Boiler in Good Condition

PROPER CLEANING, INSPECTION AND TESTING INCREASE OPERATING EFFICIENCY AND REDUCE HAZARDS

EFFICIENT operation, as well as safety, of boilers depends largely on the care which is given to the details of operation. If the boiler is systematically cleaned, is carefully inspected and if routine testing methods are followed, the results will show up in the form of reduced coal bills and longer life for the equipment.

Cleaning is especially important for it is possible to increase boiler efficiency several per cent by installation of proper cleaning equipment and by systematic cleaning methods.

Soot is an excellent heat insulator as illustrated by the curve, Fig. 1, which shows the effect on the flue-gas temperature in a boiler where the soot was allowed to accumulate. The savings possible if the soot is removed, and the flue gas temperature lowered, are shown in the accompanying tabulation.

SAVINGS EFFECTED THROUGH REDUCTION OF FLUE GAS TEMPERATURE

Per cent of CO_2	Per cent of excess air	Per cent combustible saved for each 100 deg. F. reduction
8	117	5.1
9	97	4.6
10	81	4.1
11	60	3.7
12	54	3.5
13	44	3.3
14	35	3.1

Some definite scheme of cleaning off soot should therefore be followed whether this be the use of steam lances or some form of mechanical soot blowers.

Soot should be blown at least every 24 hr., and in most plants it is customary to blow at least once during each 8-hr. shift. When the boilers are being forced at a high rating, it is necessary to blow more frequently. Some fuels are also worse than others in the amount of soot deposited, hence no definite rules can be laid down for the frequency of blowing. It is a matter which must be worked out individually.

If soot is allowed to accumulate for periods longer than 24 hr., it has been found that the fixed blower will not entirely remove the deposits. The time between

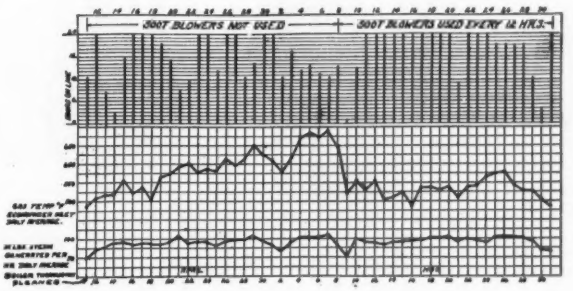


FIG. 1. TEST RESULTS ON A 1000-HP. HORIZONTAL WATER-TUBE BOILER SHOWING EFFECT OF SOOT BLOWING

cleanings should take this point into account, as one of the principal arguments for permanent blowers is that the boiler will not have to be taken off the line so often for a periodical cleaning. If the time between blowings is too long, it will be necessary to take the boiler out of service in order that the tubes may be scraped.

Assuming that a schedule of soot blowing has been laid out and the operators properly instructed as to operation, the next point for consideration should be as to how frequently a furnace and boiler should be thoroughly cleaned by taking it out of service and going over all parts with scrapers, brushes and the steam lance. The frequency of such a cleaning depends on local conditions such as how hard the boiler is being forced, the kind of coal used, type of baffling, gas velocity, etc.

Slag accumulations on the lower tube bank determine the time of cleaning about as closely as any one item. Usually in four or six weeks the boiler needs such a cleaning, even if soot blowing is regular. During the time the boiler is out of service, it is advisable to inspect the tubes to see whether cleaning is necessary. With hard feed water it is necessary to remove the scale frequently.

There is no question about the importance of scale removal, since it is estimated that scale offers a resistance to the transfer of heat 100 times that of iron of equal thickness. To produce equal steaming capacities, tubes with 1/16 in. scale will require about 15 per cent more fuel than clean tubes; with ⅛ in. scale, about 25 per cent more fuel; with ¼ in., about 40 per cent; and with ½ in., about 70 per cent.

While there are many ramifications in the detail of design of mechanical cleaners, they may be divided into two general classes; those which loosen the scale by vibration and those which cut it out. The former is applicable to either water-tube or fire-tube boilers, the latter only to the water-tube type.

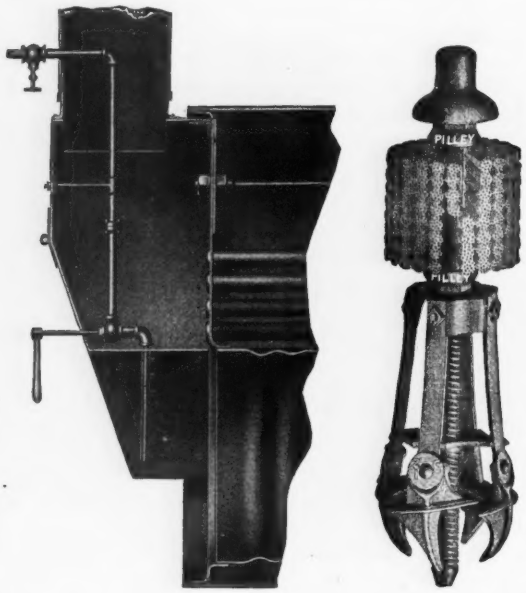


FIG. 2. ONE TYPE OF SOOT BLOWER INSTALLATION FOR A RETURN-TUBULAR BOILER

FIG. 3. SCRAPERS AND BRUSHES MAY BE USED FOR CLEANING TUBES OF H. R. T. BOILERS

While the boiler is cooling off, the ashes may be cleaned out of the combustion chamber and back connection. Also, a staging may be erected in front for work on headers and tubes and the tube cleaners, hose, and pump or compressor prepared for work. As soon as the boiler is emptied, the front caps may be removed, manholes opened and drums washed out. Several men equipped with chisels, scaling hammers, etc., may enter the drums and begin the work of removing scale. As soon as caps are off, the tube cleaner should be started. Caps, nuts, bolts and binders should also be cleaned. Headers should be cleaned by chipping the scale deposits off with chisels and scaling hammers. The entire boiler should then be thoroughly washed out.

External surfaces of the tubes, headers and drums should also be cleaned. As a rule, the tubes must be scraped to clean off the slag accumulations, after which a thorough blowing with a steam or air lance will remove the balance of the accumulations. Another method used in some plants is to wash off the tubes, after scraping, with water from a hose. Care should be taken to use no water until the setting is cool and it is better to use the hose while the tubes are full of water, as there is less danger of causing undue contraction.

Baffles and the combustion chamber should also be thoroughly cleaned. Sometimes the baffle walls are scraped, in which case care should be used not to up-end any of the baffle tile when the wall is of that type of construction.

Boiler Inspection Must Be Thorough

Often it is assumed that boiler inspection should be left entirely to inspectors sent out by insurance companies. This is all well and good, except when emergencies arise between their visits, and further, it may fall to the lot of the operator to be called away from his plant to inspect and pass judgment upon old boilers which have never been introduced to an inspector.

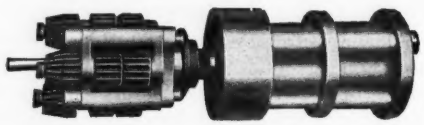


FIG. 4. TUBE CLEANER FOR THE REMOVAL OF SCALE IN A WATER-TUBE BOILER

Knowledge of boiler operation alone will not guarantee that an operator will make a good inspector, for he must gain a certain amount of inspection experience, and develop a keen sense of inquisitiveness and judgment which will enable him to sense trouble and reach quick and accurate conclusions. For a complete inspection, knowledge of mathematics is required sufficient so that an allowable working pressure may be established, not only for the component boiler parts but also for the boiler as a whole.

Local or plant-operator inspection is ordinarily concerned not with calculations of boiler strength but in watching for, or following the development of defects such as bulges, cracks, warping, pitting and corrosion which may progress from day to day and which should be reported to the insurance inspector on his regular visit. If the defect becomes serious, the local inspection may lead to shutting down the unit and requesting the insurance inspector to make a special visit.

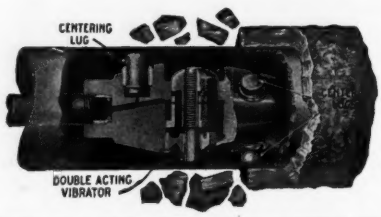


FIG. 5. VIBRATOR TYPE OF SCALE REMOVER SUCH AS USED IN H. R. T. BOILERS

Boiler inspection starts at the steel mill where the boiler manufacturer closely watches the plates and bars which are to be shipped to his specifications. A further inspection follows in the boiler shop, to assure all parties concerned that the state law and boiler code are being complied with. Large units which are erected in the field should undergo a rigid inspection during erection, and all boilers should be given an approved hydrostatic test before being placed on the line.

Permanent Records Should Be Kept

It is at this stage that all permanent records of the boiler should be complete. First there is the record of steel analysis; then the standard specification form made out by the boiler manufacturer. Each item shown on these reports should be checked by actual measurement, reading of plate stamps, etc., before the brickwork has progressed to the point where it is difficult or impossible to obtain this information. Copies of these records will be required by the insurance company before it assumes the risk.

Up to this point inspection consists essentially of checking specifications and workmanship. When the boiler has once been put on the line, the problem takes on an entirely different aspect. The actual work becomes dirty, and more difficult. Variables enter in which are often hard to detect or follow in their progress. The problem has become one of a continual fight against the ravages of service so that the boiler may have a reasonable life and returns be realized on the original investment.

Outfit necessary for this work consists of a union overall suit which fits snugly, yet allows freedom of movement. It must close tightly at the buttoned seams, wrists and ankles. A close-fitting hood should also be provided. The necessary tools are a small cross-peen hammer, a cold chisel, a small pair of pliers, a file, a gage-hand lifter, a small screwdriver and a standard test gage. A good light should also be provided. Kerosene lights are dangerous because they may be upset and catch fire. An electric extension cord is satisfactory provided it is in first class condition and all metal parts thoroughly insulated. For all around safety there is probably no better boiler inspecting light than an old-fashioned candle.

Boiler Should Be Cleaned Before Inspecting

Preparation of a boiler for inspection consists of cooling down the boiler, draining it, and cleaning it both internally and externally. Do not forget to remove the soot and ash accumulation from the combustion chamber and remove all clinker and ash from the grates.

Blowoff Pipe Needs Attention

All firebox and shell plates should be carefully gone over externally for signs of corrosion, cracks, blisters or bulges. Burned shell plates must also be watched for, particularly over the grate area. Each seam should be carefully scraped and signs of leakage and wastage noted. Special attention must be given to the blowoff pipe; look for corrosion at its connection to the boiler, see that it is free to move with expansion, and note that this pipe is protected from the direct action of the hot gases. Blowoff valves should be inspected for leakage.

Back arches should be placed so that they just clear the top row of tubes and they should not come up tight against the boiler head. The rear bearer lugs, plates and rollers should be inspected to see that they are functioning properly. Clean around rivet heads and tube beads because they may suffer from corrosion. It may be necessary to drill corroded heads to determine their thickness; these holes can later be tapped and plugged.

General corrosion and tube and seam leaks must also be looked for on the front head. Careful attention should be given to the location of the try-cocks. The water column should be of ample dimensions and connected so there will be no air traps. Tees and crosses should be used in the place of elbows on water column connections so that each pipe length can be inspected for choking by scale deposits.

No valve should be placed between the safety valve and the boiler. Damage from overhead leaks, which drip on the boiler plate, should be carefully noted. The inside heads of cross-drum boilers set in batteries should be clear of brickwork so that leaks and corrosion may be detected.

Play Safe Before Entering a Boiler

No inspector should enter a boiler until he has assured himself that the operators know of the work he is doing and that the steam connections to the boiler are locked closed. Inside the boiler, the inspector must see that the feed water does not impinge directly on either tubes or shell. He must note incrustation, cracks, pitting and corrosion on shell, tubes and heads. Note the condition of the fusible plug and remove any scale deposit.

Finally, the pressure gage must be tested. The safety valves should be set and checked by noting the pressure at which they blow off when the boiler is under pressure. Boiler brickwork, insulation, front, firedoors, and baffles should be examined to see that they are in first class repair.

Every condition noted during an inspection should be briefly but carefully written down and filed so that a complete record will be on hand at all times.

Routine Tests of Boilers and Accessories

Successful operation of a boiler depends to a large extent upon the condition of the accessories which serve to guide the fireman and insure safe operation. Tests of such equipment should therefore be made matters of routine so that any faulty condition will be promptly discovered.

Provisions for safety, of course, take precedence over equipment provided for economy and for this reason the safety valve is given first consideration. At least once each day the safety valve should be opened, either by raising the steam pressure until the valve blows off or by pressing against the lever until the valve releases. If the valve sticks or too great a force is necessary to open it, extreme care should be taken to keep the pressure below normal popping off point until the valve can be replaced or put in proper condition. The valve may be in perfect condition, but the steam pressure gage may read too high which can be determined by comparison of the readings of the steam gages on the boilers in the same battery when supplying a common header, or by checking the gage on the boiler against a test gage.

In testing the safety valve, by raising the pressure in the boiler, it is always a good plan to note the amount of blow back, i. e., the drop in pressure from the time the valve starts to blow until it closes. If the drop is too great, there will be unnecessary loss of steam and, if not great enough, the valve may be required to blow several times before the furnace conditions can be

changed sufficiently to meet the lower rate of steaming required.

Before a boiler is put into operation, after being down for inspection or repairs, it should be given a hydrostatic test to a pressure 50 per cent greater than that at which it operates. This is accomplished by filling the boiler with water and, by means of a pump, raising the pressure to the desired point. With this pressure on the boiler, inspection of all joints should be made for leaks. This test will also show up other points of weakness such as holes due to corrosion or cracks, but a hammer test should also be given the boiler before it is filled with water. Defective parts of a shell or tube will be revealed by a dead or cracked sound when struck light blows with a hammer.

Many times firemen have been deceived by indication of the water level in the gage glass. A stoppage of either connection to the boiler will cause a false indication and unfortunately either of these conditions will indicate high water level. At least once each watch the attendant should blow down the water column and note the rapidity of the return of water in the gage glass. It should be rapid, almost instantaneous, otherwise an obstruction should be looked for. The gage cocks also serve to check the indications of the gage glass, but cannot be depended upon absolutely, where they are attached to the water column as is the usual custom, for the column connection may be stopped.

Flue Gas Analysis Is a Check on Combustion

In order to determine the completeness of combustion and the tightness of the boiler setting there is no test so important as that of analyzing the flue gases for carbon dioxide, oxygen and carbon monoxide. While instruments are available for recording continuously the percentages of the most important flue gas constituents, it is well, even in these plants, to use a hand instrument occasionally for checking the recorder and, in plants where no recording instruments are in use, occasional tests during the day will prove valuable, particularly if taken at times when load conditions have changed. The equipment for making these tests and the significance of the varying proportions of the gases was discussed in the issue of January 1, 1923, and will not be repeated here.

Loss of hot water may go on unnoticed for hours or even for many days if the attendant does not regularly examine the blowoff valve for leakage. In many plants the rule is made that, before opening the blowoff valve, the attendant must feel the pipe; if it is abnormally hot, this is positive evidence that the valve is leaking. Such a condition should be remedied as soon as possible.

Scale formation in a boiler is due almost entirely to the precipitation of soluble salts from the boiler water. By the evaporation process the water becomes a saturated solution and to prevent precipitation the boiler water must be diluted. This is done by blowing off some of the water and replenishing it with fresh feed water. To determine when this should be done, many plants test their boiler water periodically for the amount of sodium chloride which it contains, this being the principal impurity where properly softened feed water is used. The test as given by Kent is as follows: A 100 cc. sample of water, drawn from the boiler water column, is colored pink with a phenolphthalein solution. After cooling and settling, sufficient 5 per cent normal sulphuric acid solution is added to destroy the color, and also four drops of potassium chromate indicator containing 20 grains per 100 cc. silver nitrate solution (strength 4.976 grains per liter) is added, while stirring the solution, until a permanent reddish precipitate forms. Each cubic centimeter of silver nitrate solution equals one grain per gallon of sodium chloride.

Testing Steam for Moisture

Water carried from the boiler by the steam is a source of danger as well as loss and should be avoided as far as possible. Water in the steam may vary from time to time due to the variations in load, water level carried and quality of boiler water. It is well, therefore, to test the quality of the steam occasionally in order to determine the limitations under which the boiler must be operated. This may readily be done by means of a steam calorimeter, several types of which are available for this purpose.

Air leaks through boiler settings are always a detriment to the efficiency of a boiler, particularly where induced draft only is depended upon, as the difference in pressure between the outside and inside of the furnace is considerable, causing air to filter through. Flue gas analyses will, of course, indicate the presence of excess air and air entering the setting beyond the furnace, but to determine the points where leakage occurs one or all of three methods may be employed. First, a lighted candle passed along the outside of the setting while the boiler is in service will have the flame drawn into crevices where leaks occur. Or, second, if the damper is closed suddenly for a minute or so after the furnace has been freshly fired, smoke will issue out through the holes in the setting. The third method is to observe the accumulation of soot on the interior of the boiler setting at times when the boiler is inspected. Points of leakage will be indicated by streaks or spots where the soot has been blown off the wall.

Many times control of combustion has been interfered with by the shifting of the damper plate on its shaft. To check the damper position, the use of a sensitive draft gage is convenient. While the stack is in service the ends of the draft gage are connected to the breeching on both sides of the damper. The position which shows the highest differential draft will be when the damper plate is across the breeching and the damper is closed. The lowest differential draft will be indicated when the damper is at right angles to its closed position or wide open.

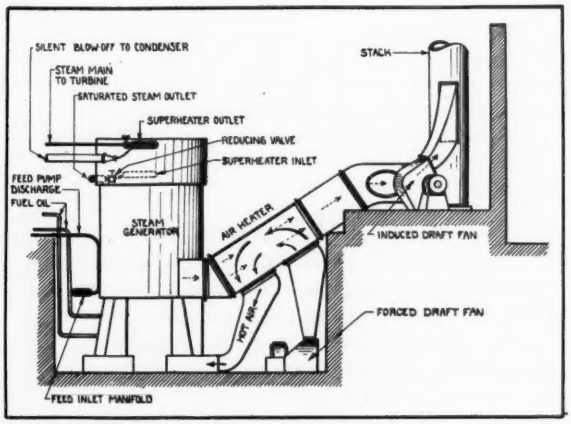
Draft gages used for indicating draft conditions throughout a boiler setting may give erroneous readings due to stoppage of the connections with soot or ash dust or they may have settled out of level. In either case the use of another gage to check the one installed is a simple matter and this test should be made at regular intervals and between times if errors are suspected.

That natural-gas gasoline can be used to advantage as a refrigerant is suggested by the fact that the "make" tanks and other parts of the equipment of gasoline plants frequently become coated with frost. Experiments recently conducted by the Department of the Interior at the petroleum experiment station of the Bureau of Mines, Bartlesville, Okla., confirm this assumption and indicate that volatile gasoline can be used to advantage in many refrigerating plants.

Steam Generated at 3200 Lb.

WITHIN the past year, announcement has come from England of the construction, by the Benson Engineering Co., Ltd., of a steam generator which will be operated under a pressure of 3200 lb. per sq. in.

At first thought, there might appear to be no valid reason for attempting a pressure which is seemingly impractical. The facts are that at this pressure and temperature steam generation has reached a critical point wherein the water and steam have the same properties; that is, the same weight per cubic foot, the same heat content, etc., and the latent heat of vaporization does not exist. If a unit volume of water is heated under a pressure of 3200 lb. per sq. in. it will turn, without boiling, into the same volume of steam when a temperature of 706 deg. F. is reached. Under these conditions we find that the density of the steam and water will be the same, or 20.1 lb. per cu. ft., whereas



GENERATOR IN WHICH THE STEAM PRESSURE WILL BE 3200 LB. PER SQ. IN.

at a pressure of say 680 lb. per sq. in. the density of the steam will be 1.46 and that of the water will be 48.7. At the critical point, the heat of the liquid will be 908 B.t.u., the heat of vaporization will be zero, and the total heat of the steam will be 908 B.t.u. At the lower pressure, the heat of the liquid will be 484 B.t.u., the heat of vaporization will be 727 B.t.u. and the total heat 1211 B.t.u.

Comparison of the total heats at these pressures is not an index of relative economy because, at the critical point, either adiabatic or constant total heat expansion would result in the steam returning to a wet condition; it must, therefore, be superheated before being used. This would result in materially increasing the total heat at the critical point, hence the true economy must be based on the B.t.u. requirements of the entire power plant.

Feed water is delivered to the oil-fired steam generator at a pressure somewhat above 3200 lb. It enters a feed manifold near the base of the generator and passes up through five coils which encircle the interior of the generator, these coils being located in an annular space formed by walls of refractory material.

Critical temperature is reached by the water after it has traversed about 90 per cent of the primary coils, at which point it is transformed instantly into saturated steam. As the steam passes on through the coils, it is slightly superheated. As it reaches the top of the generator, it is superheated to 130 deg. F. and it is then discharged into a manifold which is connected to the lower superheater manifold through a reducing valve and connection in which the pressure is reduced to a slightly superheated state at about 1500 lb. pressure and a temperature of 605 deg. The superheater then raises the steam temperature to about 790 deg. F.

Mercury Boiler Installation Promises High Economy

NEW MERCURY BOILER AT HARTFORD GIVES 50 PER CENT MORE ENERGY PER POUND OF FUEL

ALTHOUGH the first commercial installation of a mercury boiler has just recently been placed in operation, the idea of using mercury in a boiler instead of water, is not new. The possibilities of the mercury, binary vapor system have long attracted the attention of engineers, and development of actual apparatus for this service has been going on since 1914, when W. L. R. Emmet of the General Electric Company first actively took up the work.

In the installation at Hartford, the apparatus used may be considered as a substitute for a 600-hp. steam boiler. It occupies the same space and uses the same type of furnace. The gases from the furnace first pass through this mercury boiler. The vapor from this boiler passes through a single stage turbine which drives a generator. The wheel of the turbine operates inside a chamber where the vapor discharging from the turbine blades is condensed by contact with the tubes containing water, its heat of condensation being taken up in the formation of steam at 200 lb. pressure. This condenser is located above the mercury boiler and the liquid condensate runs back into the boiler by gravity, passing through a liquid heater on its way. The steam generated in the condenser-boiler passes through a superheater and then goes out to any use to which it may be put. Gases from the furnace first pass through the mercury boiler, thence through the mercury liquid heater, through the steam superheater, and finally through a feed water heater to the stack.

A vertical type of mercury boiler is used. It is cylindrical in form, and has a single tube sheet into which the tubes are expanded, and then welded. The lower ends of the tubes are free to expand. The lower ends of the tubes for about two-thirds of the way up are hexagonal in shape with the sides slightly curved. These curved sides of adjacent tubes are placed tangent to one another and are welded together at the lower edges, thus taking the place of the bottom tube sheet. The mercury is held in the interstices between the tubes.

In the present boiler there is contained about 30,000 lb. of mercury, which at the present price of 80 cents a pound is worth $24,000. The installation is designed to give from mercury and steam about 4100 kw., giving about 7.3 lb. of mercury per kilowatt. Recent experiments indicate that in future designs 4 lb. per kw. will be sufficient.

With the use of this binary vapor system, it will be possible to secure approximately 50 per cent more energy per pound of fuel.

Improved Feed Water Heater

IN THE hope that it might be of benefit to some brother engineer, should he find himself in a situation such as the writer was in, when he took charge of a certain small plant a number of years ago, I submit this sketch of a feed-water heater installation.

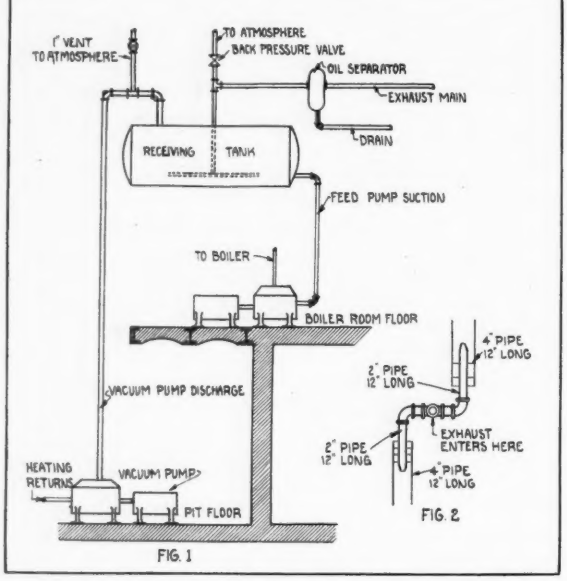


FIG. 1. ARRANGEMENT FOR RETURNING CONDENSATE RETURNS TO BOILER

FIG. 2. MIXING VALVE FOR HEATING FEED WATER

The plant had no feed-water heater and, worse still, there was no noticeable inclination on the part of the management to invest money in "any such frills."

Since the steam produced by the boilers was used principally for heating, and most of the returns from the heating system found their way to the sewer. instead of the boilers—where they should have gone—the coal pile suffered, as cold water had to be fed into the boilers to make up the deficiency in feed water.

Such a state of affairs would not long be tolerated by any good engineer. Looking over the discarded material about the place, an old steel tank (probably at one time a compressed air receiver), of about 250-gal. capacity, was found. After drilling and tapping openings for the various pipe connections, the tank was placed on a frame which was supported by the wall and roof beams, about 10 ft. above the boiler-room floor. The boiler-feed pump was set on the floor beneath the tank, and connected as shown in the sketch, Fig. 1. An old discarded vacuum pump was procured from another plant, which after considerable doctoring and the addition of a few new parts, was set in the pit under the boiler-room floor and the heating returns piped to it—the pit being made deep enough so that the returns would flow to the pump by gravity. The discharge from this pump was carried up and connected to the tank as shown in the sketch.

This provided a way to get the returns into the tank, and from the tank into the boilers. The next thing to do was to utilize the cloud of exhaust steam that was going to waste above the building roof.

Exhaust from the various pumps was connected into a main exhaust line and brought over the top of the tank, and into a tee as shown. The upper run of this tee led through a back-pressure valve to the atmosphere; the lower run was screwed into the tank and then continued down into the tank to within 6 in. of the bottom and a tee connected with the run openings crosswise to the length of the tank.

Nipples, with ells looking in opposite directions, and parallel with the length of the tank, were screwed into the tee just mentioned, as shown in Fig. 2. Two nozzles were then made, in this case of 2-in. pipe, 12 in. long, by heating and slightly closing the outlet ends. Then two pieces of 4-in. pipe, 12 in. long, were attached to the nozzles by means of stay bolts, with the outlet end of the 4-in. pipe extending 4-in. beyond the end of the nozzle. The job was completed by screwing the nozzles into the ells and running a 1-in. vent from the high point on the vacuum pump discharge to the atmosphere.

By setting the back pressure valve at about 5 lb. the exhaust steam was discharged through the nozzles with sufficient velocity to cause rapid circulation and thorough mixing and heating of the feed water, which averaged around 220 deg. F.

One objectionable feature of this arrangement is that it allows most of the sediment and scale forming materials to enter the boilers with the feed water; but, when practically all of the condensate was returned to the boilers, the scale proposition was not of such great importance, and the saving in coal consumption was at once noticeable. J. E. C.

Temperature Required to Effect Complete Atomization of Fuel Oil

IN EVERY article that I have read on the subject of oil burning, where oil temperatures are given, I have found the temperatures stated higher than good practice requires. Referring to Claude C. Brown's article, "Mechanical Atomization of Fuel Oil," in the Nov. 15

issue of Power Plant Engineering, the temperatures given for California residium fuel oil are between 210 and 270 deg. F., which I claim is unnecessarily high.

My experience with fuel oil has been confined to steamships and has been more in connection with Scotch boilers than with any other type. Several months ago a ship, equipped with three four-furnace Scotch marine boilers, of which I was chief engineer, arrived in the Los Angeles port (San Pedro) at 1:30 a. m. from New York and sailed again at 3 p. m. of the same day for Baltimore. All twelve furnaces were about one-third full of carbon and soot. As was customary, the firemen and wipers quit and new men were not recruited until a few minutes before sailing time, so we sailed with the furnaces in the same condition they were in when we arrived.

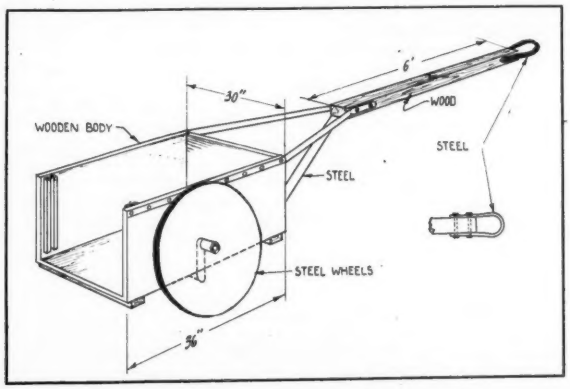
On the trip west the fuel oil was 14 deg. Baumé and it had been heated to from 230 to 240 deg. F. Leaving San Pedro, we had California residium oil of 20.1 deg. Baumé and I reduced the temperature to from 165 to 170 deg. F. After the 13-day trip to the Panama Canal, all the carbon had disappeared from the furnaces.

Oil was fed into furnaces by means of a mechanical atomizer and forced draft was used. The boilers had internally fired corrugated furnaces and there was no brickwork used.

Oakland, Cal. JAS. M. BOLAR.

Underslung Cart Is a Handy Carrier

IN ONE power plant a small carrier, which is suitable for heavy loads, is in successful use. The construction is similar to the accompanying sketch. Two small wide banded wheels, are attached to a cranked axle and



THIS SMALL CART LOADS WITHOUT LIFTING AND CAN BE DUMPED. IT IS MOVED BY HAND OR ATTACHED TO A TRUCK AS A TRAILER

support a three sided body, the base of which is about 6 in. above the ground line. A long pole tongue is fitted, which facilitates hand use, or the coupling can be attached to the rear of a truck for a longer haul. The advantages of this cart are apparent for handling heavy loads. A barrel of oil or lubricant can be placed into the cart by hand. Tilting the barrel without lifting, places one edge on the cart body where it is readily pushed in place. It is unloaded with similar ease. For the transportation of bricks, ashes, earth, grates, or similar loose materials, the rear end can be closed with detachable boards. In loading, the materials can be handled to an advantage because the body is low and the high lift is avoided. In unloading, the contents can be dumped without the labor of a second handling. This cart will accomplish work which is impossible with the wheelbarrow and also enter places where it is impossible to use a truck. The cost of making up this cart is low in proportion to the service which it will render.

Washington, D. C. G. A. LUERS.

Steel Stack Serves as Derrick Mast in Handling Other Stacks

IN DISMANTLING and erecting three smokestacks at the Nassau branch of the Brooklyn Union Gas Co., the contractors took advantage of the situation by using one of the stacks as a mast in forming a derrick by

SEVEN-TON STACK HOISTED FROM ANOTHER STACK SERVING AS A DERRICK MAST

means of which the other stacks were handled. These stacks were 95 ft. high and measured 48 in. in diameter. Each stack weighed 13,680 lb., being constructed of ¼-in. steel. The roof over the stacks was slate resting on light angle iron strips and would just about stand the weight of a man, so it was impossible to work from this roof.

First the workmen removed some slate from over the building wall at the edge of the roof and then rigged up a 72-ft. pole weighing about 2 T. on this wall. They then proceeded to rig up an 82-ft. pole alongside of the building and dismantled and re-erected the end stack. Next they had this stack secured with an extra heavy back guy, then rigged the 72-ft. pole on this stack by lashing a steel wire around the stack and one around the base of the pole and securing a swivel in both lashings. The second stack was picked up and swung around to the 82-ft. pole, then lowered to the ground. When the second stack had been re-erected, the 72-ft. pole was then rigged on the center stack to handle the last stack.

Chicago, Ill. GEO. F. PAUL.

CHANGES OF THE damper position should be made gradually. During periods of high steam pressure, the damper should not be closed entirely off in order to let the pressure drop; nor should the damper be opened full to get the pressure up. This causes the draft and air supply to vary excessively. Automatic damper regulators that are not properly adjusted cause similar variations.

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CONTENTS

Water-Tube Boilers 2
Superheat Increases Efficiency of Steam Generation and Use 3
Water Baffling in Boiler Drums Is Needed to Prevent Priming 5
Details of Standard Water-Tube Boilers 7
- The Babcock & Wilcox Co 7
- Phillips Badenhausen 8
- The Bigelow Company 9
- The Casey-Hedges Co 9
- The D. Connelly Boiler Co 10
- Edge Moor Iron Company 11
- Erie City Iron Works 11
- Heine Boiler Company 12
- E. Keeler Company 13
- The George T. Ladd Company 13
- John Mohr & Sons 14
- Murray Iron Works Company 14
- John O'Brien Boiler Works Company 15
- Page Boiler Co 16
- Springfield Boiler Co 16
- Union Iron Works 17
- The Wickes Boiler Company 17
- Kingsford Foundry & Machine Works 18

Horizontal Return Tubular Boilers 19
Setting the Horizontal Return Tubular Boiler 21
Adaptability of Vertical Tubular Boilers 24
Locomotive Type Boilers 27
Scotch Marine Boilers 28
Strength of Boiler Parts 30
Furnace Construction 35
Details of Special Baffles 36
Construction of Bridge Walls 37
Suspended Arches Gaining in Favor 38
- American Suspended Arch 39
- Bigelow Suspended Arch 39
- Detrick Suspended Arch 39
- Illinois Suspended Arch 39
- Laclede-Christy Suspended Arch 39
- Liptak Suspended Arch 40
- McLeod & Henry Suspended Arch 40
- National Supended Arch 41
- Waite & Davey Air Cooled Arch 41

Improvements in Furnace Lining Material 41
Condenser Tube Failures 42
Proper Grate Design Important 43
Rocking and Dumping Grates 44
- Armstrong Interlocking Shaking Grates 44
- Auburn Clear-Cut Grates 45
- Brownell Rocking and Dumping Grates 45
- Dean Dumping Grates 45
- Erie City Shaking Grate 45
- Kelly Rocking and Dumping Grate 45
- Loco Shaking Grate 46
- The Martin Rocking and Shaking Grate 46
- McClave-Brooks Grate 46
- Murray Triple Acting Rocking Grate 46

Hand Stokers 47
- Armstrong Interlocking Stoker 47
- Auburn Hand Stoker 47
- Cokal Chainless Stoker 48
- McClave Hopper Feed Hand Stoker 48
- National Stoker 49
- Perfection Hand Stoker 49
- Vogt Hand Stoker 49

Mechanical Stokers and Details of Furnaces for Special Fuels 50
Drive and Speed Control of Mechanical Stokers 52
1200-Lb. Boilers a 1923 Development 55
Mechanical Stokers for the Power Plant 56
- American Engineering Company 56
- The Babcock & Wilcox Company 56
- Combusion Engineering Corporation 57
- Detroit Stoker Co 58
- Illinois Stoker Co 58
- Laclede-Christy Clay Products Co 58
- Sanford Riley Stoker Co 59
- B. F. Sturtevant Co 60
- The United Machine & Mfg. Co 61
- Westinghouse Electric & Mfg. Co 61
- McClave-Brooks Company 62

Furnace Design Important in Burning Oil 63
- Best Steam Atomizing Burner 64
- Bethlehem Mechanical Atomizing Burner 64
- Coen Mechanical Atomizing Burner 64
- Quinn Steam Atomizing Burner 65
- Enco Steam Atomizing Burner 65
- Foerst Steam Atomizing Burner 65
- Lenz Steam Atomizing Burner 65
- Lockett Steam Atomizing Burner 65
- Morse Mechanical Atomizing Burner 65
- Peabody Mechanical Atomizing Burner 66
- Schutte & Koerting Mechanical and Steam Atomizing Burners 66
- Tate-Jones Steam Atomizing Burner 66

Gas Can Be Burned with Higher Efficiency than Other Fuels 66
Furnaces for Burning Wood Refuse 68
Application of Pulverized Coal to Boilers 71
Boiler Equipment 73
Types and Details of Safety Valves 76
- American Pop Safety Valve 77
- Ashton Pop Safety Valve 77
- Consolidated Pop Safety Valve 77
- Crosby Safety Valves 78
- Lonergan Safety Valves 78
- Lunkenheimer Safety Valves 78

Steam Outlet and Blowoff Valves 79
- Crane Stop Check Valves 79
- Davis Stop and Check Valve 79
- Eclipse Non-Return Valves 79
- Edward Non-Return Stop and Check Valves 80
- Foster Engineering Co 80
- Jenkins Non-Return Valves 80
- Lagonda Boiler Valve 80
- Lunkenheimer Non-Return Valves 81
- Schutte & Koerting Non-Return Valves 81
- Strong Non-Reurn Stop Valves 82

Blowoff Valves 82
- Crane Blowoff Valves 83
- Lunkenheimer Blowoff Valves 83
- Everlasing Valve 83
- "Ferrac" Valve 83
- Homestead Blowoff Valves 84
- Jenkins Blowoff Valves 84
- Okadee Valve 85
- Schiller Blowoff Valves 85

Hinged Door for Sidewalk Coal-Holes 85
Boiler Piping Arrangements 86
Safety First Should Be Feature of Boiler Piping 88
Practical Ways of Obtaining Boiler Economy 90
Feeding and Blowing Down Boilers 92
Keeping the Boiler in Good Condition 93
Steam Generated at 3200 Lb 97
Mercury Boiler Installation Gives Promise of High Economy 97
Letters Direct from the Plant: Improvised Feed-Water Heater. Temperature Required to Effect Complete Atomization of fuel oil. Underslung Cart Is a Handy Carrier. Steel Stack Serves as Derrick Mast in Handling Other Stacks 98
Editorial: 1924 to Be an Interesting Year. Does Your Record System Fulfill Your Needs? Power Show Deserves Support 101
Many New Developments at Power Show 102
Engineers to Exercise Their Brains 117
Industries of New England Study Power Situation 117
Chicago A. S. M. E. Will Give Day to Power Meeting 117
Edison Medal Awarded to John Lieb 118
Congressional Action for Coal Control Proposed 118
Oil Circuit Breaker Is Four Stories High 118
News Notes 118

1924 to Be an Interesting Year

While the year 1923 has been one of spectacular interest due to the many announcements of new developments in the field of power plant design, the year 1924 should be of even greater interest because it will be a year of achievement.

During the course of the year, operating data should be available on the mercury turbine, the 1200-lb boilers, on the special schemes for bleeding and using steam from the main units, air preheating, use of auxiliary boiler heating surface in the furnace walls and for the many new develpoments in accessory equipment which have been announced during 1923.

Does Your Record System Fulfill Your Needs?

Before we begin the work of the new year it might be well for us to take account of last year's work in order to determine just where we stand. Can you, for instance, in looking back over your records tell at a glance exactly how much was spent for the operation of your plant last year and how much it earned? Can you tell how much more, or less, coal was burned last year than the year before? Do you know with a reasonable degree of certainty how much was saved as a result of those improvements which you effected in the boiler room? If the boss calls up this afternoon and wants to know why you have recommended those changes in the feed heating system, can you show him, in black and white, that the proposed changes will pay for themselves in a year or two years as the case may be? Do you know how much money was spent last year for oil, for packing, for labor, etc.? Do you know whether your equipment is operating at efficiencies comparable with the usual efficiencies of modern apparatus? Can you answer these questions and others of a similar nature?

If you can answer them accurately and with a minimum amount of effort, your system of records is probably well suited to your requirements. On the other hand, if many of them are unanswerable or if days or weeks of investigation are necessary to get answers, it is time for you to devise and use an adequate system of records.

Every power plant, large or small, should have some system of records which will at all times contain the information necessary for the proper and efficient management of the plant. No matter how small the plant, no man's head is big enough to contain all the facts and figures relating to that plant. Even if it were big enough, what would be the use of filling up good brain space with drab figures which might just as well be put on paper? Use your head for something else than a mere warehouse for plant statistics. Warehouses are usually musty.

Put your operating data on paper and keep it in such form that, if a man asks you how much you paid for coal in June of 1923, you don't have to spend a week finding the answer to that question. Records need not be complex. As a matter of fact that is just what they should not be. They should be as simple as it is possible to make them and yet yield the required information.

Are *your* operating records adequate? Do they fulfill your needs? Stop for a moment and ask yourself some of the foregoing questions. If you can answer them, all well and good, go on with your next year's work. If, however, you cannot answer them, it will be well worth your while to spend some time improving your record system before you do anything else.

Power Show Deserves Support

Although the Power Show this year was more comprehensive than that of last year and was also better from the standpoint of attendance, one feature was lacking which is needed to make the Show complete, namely prime mover equipment.

Probably the manufacturers of turbines and engines feel that from a sales standpoint the expense of exhibiting would not be justified. It is hardly to be expected that turbines or engines would be sold on the floor of the Show for equipment of this type is not sold "over the counter." Neverthless there are certain advantages to be gained by participation in the show which may not be quite so tangible as orders, but which would eventually reflect back to the exhibitors.

In lending support, these manufacturers would be aiding in the movement to make the annual meeting of the A. S. M. E. and the Power Show the culmination of the year's effort in mechanical engineering and in making this double attraction of such worth as to warrant the effort required for engineers to travel a thousand or more miles in order to obtain first hand impressions.

In a show of this kind, all of the value for the manufacturers does not lie in the contact with engineers. A goodly share of the value should come from the contact of manufacturers with each other.

In securing such a contact it is not enough that the publicity department be sent to handle the show. The executives of the organization and the designing engineers should participate. At this year's show were plenty of men whose salaries run well into five figures who found time to explain the ideas behind the developments of the organizations which they represent. Naturally both visitors and representatives of the other companies gained a contact with these men not ordinarily possible.

Elaborate and expensive exhibits are unnecessary. Models, photographs, drawings and parts frequently are more interesting than the assembled machine. Best of all is to have representatives present who speak with the authority of intimate knowledge.

It is to be hoped that next year the Show will even more completely represent the industry.

Acknowledgement

IN THE PREPARATION of this issue of Power Plant Engineering many sources of information were called upon, principal among which were the various manufacturers whose equipment is described. It must be obvious, however, that in any work of this kind, it is impractical to give direct credit to all the sources from which information was obtained. Use was made of papers published before engineering societies, works of eminent authors in the engineering field, government reports and bulletins, etc. In most cases the data so obtained has been so interwoven as to make direct mention of the source difficult or impossible. We wish, therefore, in this manner to thank and make public acknowledgement to all those who contributed, directly or indirectly, to the making of this issue.

Many New Developments at Power Show

INTERVIEWS WITH EXHIBITORS BRING TO LIGHT NEW DEVICES AND IMPROVEMENTS TO EXISTING EQUIPMENT

IF YOU were a visitor at this year's Power Show, it is quite likely that you were impressed with two things. First, the size of the show as compared with that of last year and, second, by the evidence of certain trends which were indicated by the exhibits. Last year the show was made up of 120 exhibits of which about 90 were directly of interest to power plant men. This year there were some 270 exhibits of which at least 160 were of direct interest to the power industry and the balance of particular interest to the allied mechanical applications and engineering.

Tendencies and trends in practice might be summed up with the word "intelligence." That the transmission of intelligence, the liason between the boiler room, the turbine room, the dispatching department and the management is of far greater importance than ever before in the minds of engineers was indicated to a marked degree by the numerous exhibits which specialized on some form of device by which a better knowledge of plant operation might be secured. Many new instruments such as remote water level indicators, electrical CO and CO_2 recorders, station load indicators, signaling systems between the various parts of the plant, which are a definite aid in making possible intelligent and efficient operation of a plant, have been developed and were shown this year.

Not from such a standpoint alone was this year's Power Show of importance to the industry, but also because it gave to both the operating men and the designers of plants an indication of how the manufacturers are keeping in step with progress. Practically all of the exhibitors pointed out certain refinements that have been made in their apparatus, which have improved it for operation under the new era of intensive effort toward a reduction of operating costs and of maintenance labor. In addition, many new developments have been made along the line of the use of higher pressures, of higher temperatures and the working of plants to the limits of possible capacity. In other words, the slogan has been, "To corral the elusive B.t.u."

In order to give engineers who were unable to visit the show some idea of what was there, and also to give those who saw the exhibits some thoughts regarding the show to compare with their own, the following paragraphs will touch on some of the high points and impressions which were gained by actual contact and by interviews with the exhibitors. In many cases, the comments of the exhibitors have been obtained with a view to securing their ideas on what the future holds for the power plant field and what part their particular devices and apparatus will play in the developments of the next few years.

Payne Dean, head of the Payne Dean Co., Ltd., explained in some detail the new totalizing station load indicator and signaling system which has recently been developed by this company. A sending panel is located in the switchboard control room, receiving stations in the turbine room, a large total load indicating unit in the turbine room and, if desired, one of these may be located in the boiler room.

On the load indicator are four numerals reading 1, 2, 3 and 4. If it is desired to increase the load, say 20,000 kw. and the load is to come on in 30 min., the control room signals by mean of the demand indicator at each receiving station and, at the same time, this is indicated on the large totalizing meter. The numeral 2 would then be lighted on this meter, which would show the turbine-room operator that the load is to be increased in 30 min.

Usually, there is a receiving station at each turbine so that the control room can signal directly to any machine. One of the dials on both the receiving and sending stations is a turbine selector indicator which shows the number of the turbine to be put in service. As the turbine-room operator receives the various signals, such as telephone, start, stop, etc., he repeats the signal back to the sender.

In calling attention to the problem of ash-hopper design, Mr. Dunbar, of the Baker, Dunbar Co., pointed out that the construction must be such as to resist heat and the action of acid water. In the experience of this organization, a cast-iron construction with a tile lining is considered essential to meet these conditions. According to Mr. Dunbar, the interlocking tile construction which is used is necessary in order to prevent the possibility of knocking out a tile when using a slice bar. At the same time, the construction permits the removal of any individual tile.

Another feature on which considerable emphasis was placed is the arrangement for cleaning the water-collecting troughs. Each time the ash gate is operated a scraper cleans out the collecting troughs on each side so that the ash does not have a chance to pack down and interfere with the flow of water.

Last year the Vincent Gilson Co., of New York, represented the Diamond Power Specialty Corporation, the Carling Turbine Blower Co., and the Falls Automatic Engine Stop. This year the same arrangement

has been continued with an exhibit quite similar to that of last year. Mr. Vincent, in commenting on the soot blower business, stated that the Diamond people are installing soot blower units on about 2,000,000 boiler horsepower a year. One job of particular interest which has been sold is the new Hudson Ave. station of the Brooklyn Edison Co.

Albert L. Carlson, of the Carling Turbine Blower Co., called attention to the new blower design which has recently been brought out by this organization. A change has been made in the fan blade design from the straight blade to the radial type. The fan casing has been changed by the addition of guide vanes which reduce the eddy currents and are an aid to efficient operation. This type of construction, according to Mr. Carlson, has made a unit which is 20 per cent more efficient than the old one and which is practically noiseless in its operation. One feature of the turbine is the use of monel metal blades.

Marine plant practice has furnished a device which offers interesting possibilities in the stationary plant field in the shape of an augmenter for improving the maximum vacuum obtainable with an ordinary vacuum pump installation. The C. H. Wheeler Mfg. Co., Philadelphia, Pa., exhibited its augmenter, which on shipboard is put between the condenser and the twin-beam air pump and operates on low-pressure steam from the auxiliary exhaust line. The idea can be applied in stationary practice where it is desired to increase the vacuum without spending much money. Charles Lang, New York manager for the company, also commented on the improved design of the inter and after condenser.

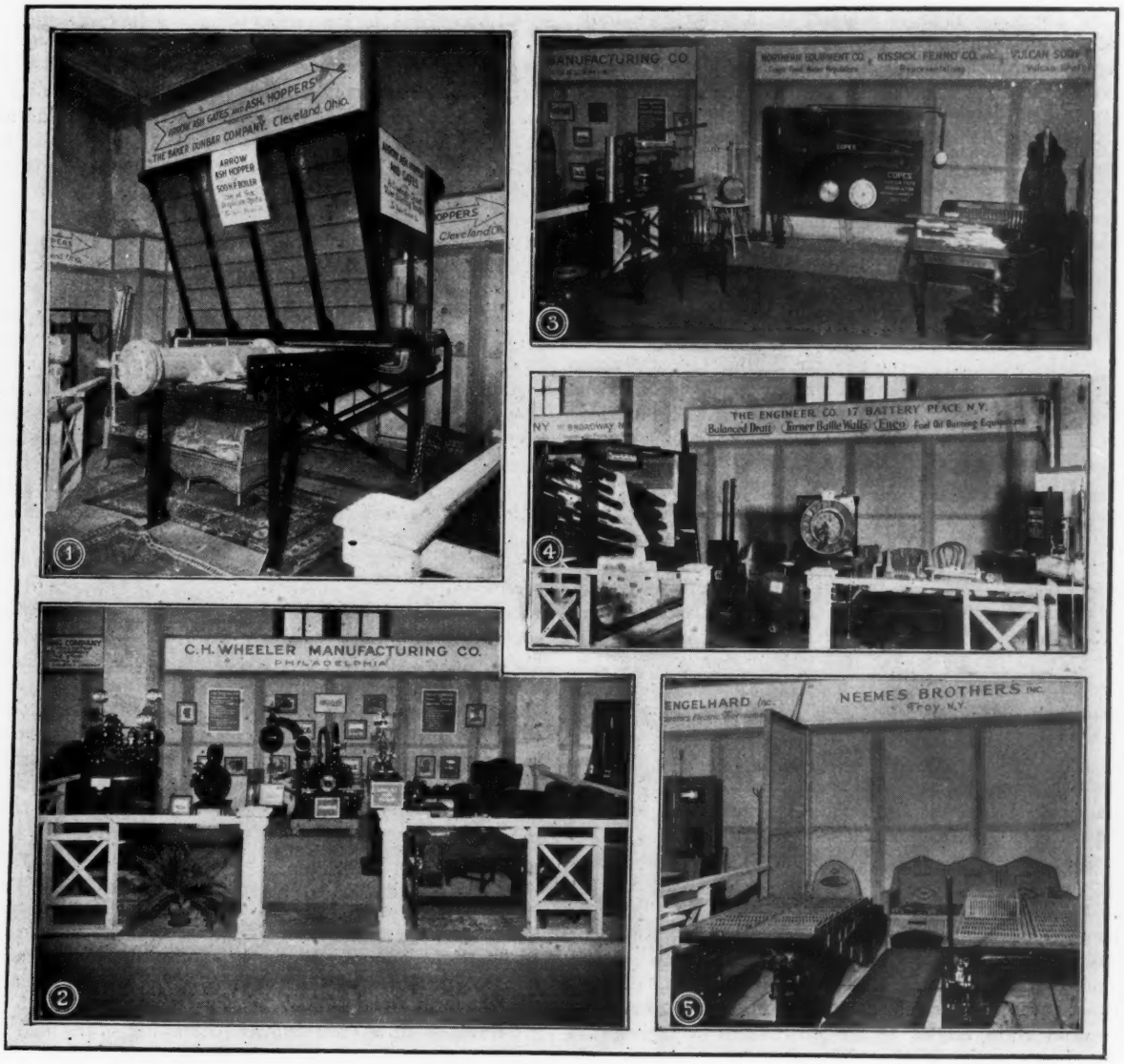

FIG. 1. CAST IRON ASH HOPPERS WERE FEATURED BY THE BAKER DUNBAR CO. FIG. 2. C. H. WHEELER MFG. CO. SHOWED AUGMENTER AND INTER AND AFTER CONDENSER. FIG. 3. FEED WATER REGULATORS FORMED PART OF EXHIBIT OF NORTHERN EQUIPMENT CO. FIG. 4. INCLINED BAFFLE WALL CONSTRUCTION WAS A FEATURE OF THE ENGINEER CO. EXHIBIT. FIG. 5. SHAKING AND DUMPING GRATES SHOWN BY NEEMES BROS.

This design has been changed so that the makeup water passes through separate passages hence does not affect the deaerated condition of the condensate.

E. W. Nick, president of the Northern Equipment Co. of Erie, Pa., has been browsing around in Europe for some time during the past few months and picked up a new type of remote water level indicator. This device will be added to the line of the Northern Equipment Co. Mr. Nick believes that the time has come when there is a definite demand for a water-level indicator which can be placed on the boiler-room control board. Increasing size of boilers and the tendency to reduce the labor and operating costs to a minimum are the two main causes which have brought about this demand. This particular indicator depends on the operation of a diaphragm, one side of which is balanced by a constant-head water column, maintained by steam condensed from the boiler and a variable water column which depends on the level of the water in the boiler.

Another new device shown was the valve-opening indicator which has recently been brought out. This instrument indicates the valve opening of the regulator hence gives the fireman a check on the regulator operation. In addition to the regular line of Copes regulators, a regulator for 1200 lb. pressures was also shown. For this pressure, a flanged stuffing-box is used. Mr. Nick pointed out that the operation of regulators at this pressure is even better than at lower pressures since the temperature difference between the water and the steam in the regulator is greater at the higher pressures. The action of the regulator is therefore more rapid. Regulators are now being made up to 6 in. in size, seven of these regulators having recently been sold to the Detroit Edison Co. for use in the Trenton Channel plant.

During the past year the Vulcan Soot Cleaner Co. has brought out a valve-in-head soot blower which was exhibited. According to F. W. Linalser, vice-president, the main feature of this unit is the sliding valve. The rotation of the element causes the disc to slide over the seat, leaving a full opening and straight flow steam passage. When the cover of the blower head is taken off all of the valve parts can be lifted out.

Several changes have been made in the construction of radiant heat superheaters which are built by the Power Specialty Co., of New York City. A. Bradley, New York sales manager of the company, stated that when the radiant heat superheater was exhibited last year the superheating elements were made up of steel tubes incased in case-iron blocks. The steel tubes were bent at right angles at the junction with the row of cast-iron encasing blocks. The present construction is to make, in place of the separate blocks, a steel casting the full length desired and cored out inside to allow for the passage of the steam. These elements are then connected at the top and bottom with a straight piece of steel pipe.

One slight change has also been made in the method of economizer cleaning. This economizer consists of steel tubes onto which are shrunk cast-iron rings. The cleaning as originally designed was to be taken care of by washing during operation. It has been found advisable, however, to use the washing method when the gases are not passing through and, as an adjunct, a permanent soot blower installation has been added for cleaning while the gases are passing through the economizer.

In order to give some idea of the use of inclined-baffle-wall construction, K. L. Martin, president of The Engineer Co., New York City, stated that 250,000 hp. of boilers have been equipped with Turner baffles during 1923. One feature of construction which has been developed by this organization is the curtain wall. Where curtain walls made of brick had to be about 9 in. thick, it has been possible to reduce this to 4 in. with the Turner construction and increase the gas passage by 5 in.

The Engineer Co. also exhibited the Enco balanced draft system and the Enco oil burners and air registers. Mr. Martin, in commenting on the oil-burning situation, stated that work is especially active along the Atlantic and Gulf coasts where it is possible to secure oil by water delivery. Activity is also increasing in Montana and Oklahoma since new fields are being opened in those sections. The Rock Island R. R. is to change over four plants in Oklahoma to oil fires. Some of the important installations in the East are N. Y. Central R. R., the New York, New Haven & Hartford R. R., International Paper Co., and the American Writing Paper Co.

Keasbey & Mattison Co., of New York City, represented by Chas. Allis, had an exhibit quite similar to that of last year, in which the possibilities of heat loss prevention by the use of asbestos and magnesia insulation, were presented. In this exhibit, steam was supplied from a small boiler to pipe lines of various sizes which were equipped with different thicknesses of insulation. Thermometer readings then gave some indications as to the heat loss in the different cases.

One of the most interesting pieces of work which has been handled by the M. H. Detrick Co., of Chicago, during the past year has been the arch construction for the 3060-hp. Stirling boilers which have been placed in the plant of the Cleveland Electric Illuminating Co. These boilers, which are among the largest in the world, are fired with pulverized coal and the particular design calls for quite an extensive roof area over the burner inlets. L. Hosbein, general manager for the Detrick organization, in commenting on the exhibit, discussed this installation and showed some photographs of the furnaces. Another installation of interest is that at the Lakeside plant of the Milwaukee Electric Railway & Light Co. which has recently been increased in capacity. The exhibit also comprised a model of the Detrick suspended arch, in which a slight change has been made in the end construction. Formerly a bull-nose arrangement has been used, but the end of the arch is now built more like the ignition arch with fan construction.

Business in the shaking and dumping grate field is quite active, according to O. J. Vashrow, production manager of Neemes Bros., Inc., of Troy, N. Y. In addition to showing the shaking and dumping grate, which has been exhibited at various other shows this year, the straight dumping type was included. The business of this organization has been better this year than any year since 1918, and prospects appear to be good for work next year.

At the exhibit of the D. Connelly Boiler Co., Cleveland, models of curved-tube and sectional-header and straight-tube boilers, arranged with transparent ends, were used to give an idea of the circulation of water and steam. As pointed out by E. C. Welch, of the Connelly organization, the steam is separated from the water in one drum and passes through drying tubes into

a second drum before being discharged into the piping. This results in a slight superheat. One interesting installation which is now being made is for the Texas Co., at Galveston, Texas, where eight 750-hp. boilers are to be installed. These boilers will have integral economizers.

During the past year, considerable attention has been given by the Hagan Corporation, of Pittsburgh, Pa., to a study of the chemical reactions taking place inside the boiler, due to treatment of feed water. In commenting on this phase of the company's work, H. A. Jackson, chemical engineer, stated that the Hagan organization has been working in conjunction with the Bureau of Mines in carrying out some research to determine the causes of scale and how it may be overcome. One result of this work has been the development of the Hagan Deconcentrator, in which water is drawn from the boiler at about the water level and passed through the deconcentrator which is filled with a special grit. It has been found that, by passing from 10 to 25 per cent of the boiler water through in this way, it has been possible to reduce the concentration, where soda ash is used for treatment, to a very low degree. It is expected that the complete results of the research will be available shortly.

W. R. Holmes, New York manager for the Geo. T. Ladd Co., in commenting on the results which have been secured with large boiler settings, stated that in his opinion remarkably little trouble has been experienced with such installations as that at the River Rouge plant of the Ford Motor Co. The Ladd boilers have been used for extending this plant, as described in the Dec. 1 issue of Power Plant Engineering, and the changes in the setting were of quite a minor character. The Ladd Co. is making a number of installations and business conditions for next year appear to be quite favorable.

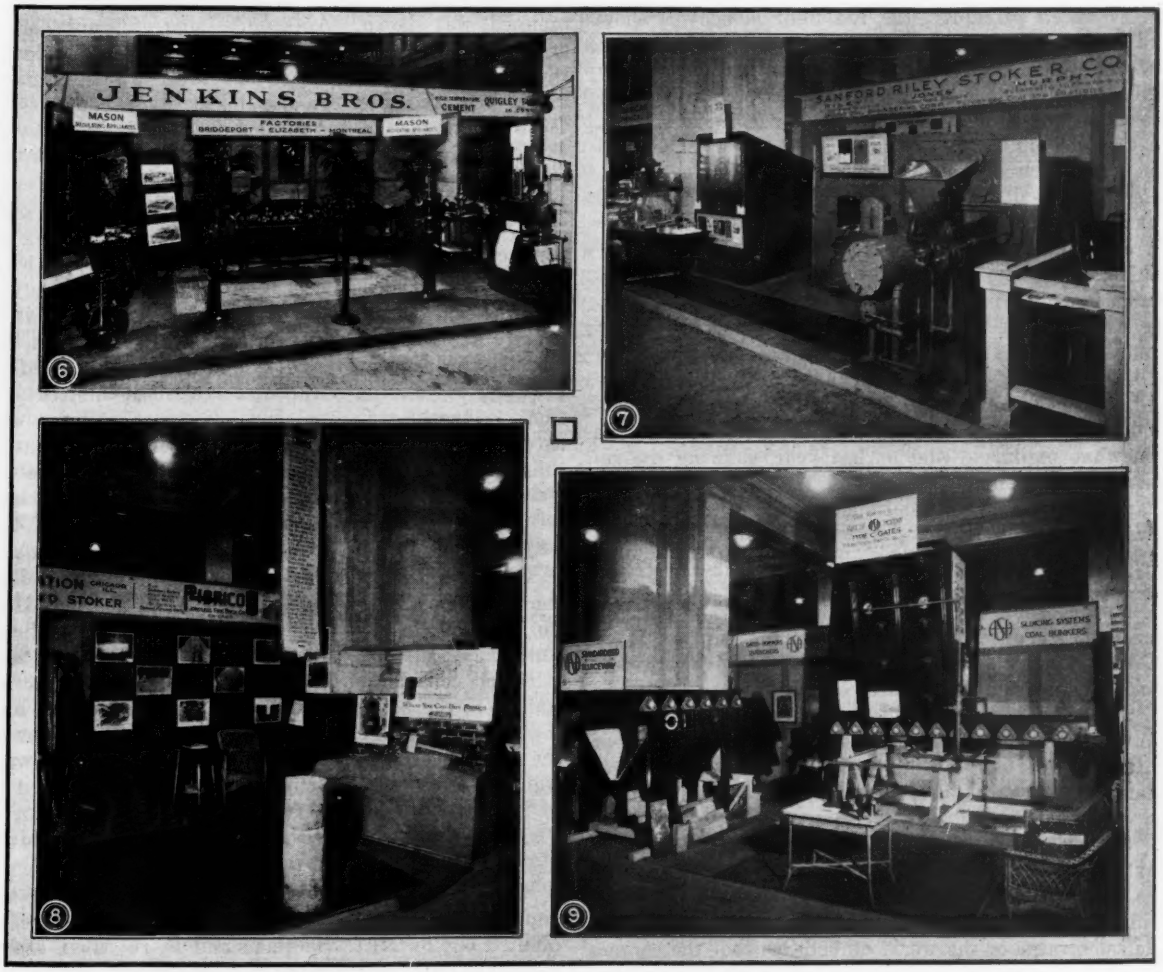

FIG. 6. BRONZE AND IRON VALVES COMPRISED PART OF JENKINS BROS. EXHIBIT. FIG. 7. LATERAL RETORT STOKER SHOWN IN OPERATION BY SANFORD RILEY STOKER CO. FIG. 8. SECTION OF FURNACE WALL WITH MONOLITHIC LINING FEATURED BY JOINTLESS FIRE BRICK CO. FIG. 9. CAST IRON SLUICE-WAYS AND ASH HOPPERS SHOWN BY ALLEN-SHERMAN-HOFF CO.

In the exhibit of Jenkins Bros., of New York City, a full line of Jenkins bronze and iron body valve and mechanical rubber goods was shown. In addition one of the valves was equipped with the Dean control system.

The Mason Regulator Co., of Dorchester Center, Mass., also occupied a portion of this booth and in addition to showing its line of reducing, excess-pressure and balanced valves, the Simmons system of temperature

control was presented. This system depends for its action on thermo-couples located in the furnace and in the flue-gas uptake which operate potentiometer controllers. Each controller actuates a solenoid regulator, one of which is furnished for each boiler, and connected to operate the individual boiler damper or blast gate, thus regulating the air supply. Each potentiometer controller also actuates a signal system. If proper temperatures are obtained, a white light will show while, if furnace conditions are not quite right, a red light will alternate with the white light. If these conditions are not remedied promptly, the red light alone will show and continue to show until proper temperatures are restored. In case of excessive stack temperature, a green light shows and a Klaxon horn sounds. Extensions of the signal system may be carried to the engineer's office.

Considering the fact that old fire brick has been calcined and shrunk in operation, it is quite logical to assume that the use of such brick, in the ground form and mixed with a high temperature cement, offers not only an economical material for furnace lining and repair work but also one which will stand up under high temperature conditions. This is the viewpoint of the Quigley Furnace Specialties Co., of New York City, represented by H. T. Matthew. The Quigley organization will concentrate on this idea during the coming year and expects to have as good success in getting it across as during the past year or two. This year's exhibit was somewhat similar to that of last year, showing the resistance of ground fire brick and Hytempite to sudden changes of temperature. In addition, sections of furnace walls were shown, giving an idea of the method of construction where the ground fire brick mixture is used as fill.

Besides showing motion pictures of what goes on inside the furnace during operation, the Sanford Riley Stoker Co., of Worcester, Mass., showed its lateral-retort stoker set up complete and in operation. According to O. C. Sheldon, who is publicity manager for the organization, the Riley business has been good all the year with the first half of the year possibly slightly better than the last half. Prospects for next year appear to be very good.

Sanford Riley, in commenting on the show, stated that in his opinion it was of such educational value to the manufacturers themselves as to warrant the effort and work put into the exhibits. Without considering the sales value of the work, he believes that the contact which the manufacturers get with one another and the knowledge of the various products is well worth while. Mr. Riley attributes the slight falling off in business the latter part of this year, to the fact that the work earlier in the year was concentrated on getting plants ready for the winter peak. The urgency of that has passed, hence the slight let-down.

Some years ago a man by the name of Bernitz, a boiler-room repair man for the Boston Elevated Co., and who had formerly been on an erection gang for the Babcock & Wilcox Co., conceived the idea that, by admitting air through the side walls of the furnace, it might be possible so to reduce the temperature at that point that clinkering troubles would be eliminated. His first method was to leave out the fire clay between the ends of the brick in that section of the furnace wall which came in contact with the burning fuel bed. This worked fairly successfully and led to the development of the special air-cooled block which is now used for this purpose. Bernitz sold his right to the idea but the work is still carried on under his name by the Bernitz Furnace Appliance Co., of Boston, Mass. A. E. Smith, president of the company, who commented on this human interest angle of the business, stated that their business was rapidly growing, as operating men have been quick to realize the value of the system.

At the exhibit of the B. F. Goodrich Co., Akron, Ohio, a new type of bearing for operation under water or where water containing gritty material is to be pumped, was shown. An outer casing of bronze, steel or other metal is used. On this outer surface is vulcanized a soft rubber surface which is afterward ground to the required size. A spiral groove is then cut on the inner surface of the rubber and it is said that the water which circulates through this groove prevents the gritty material from cutting the bearing.

One factor which has had a strong influence in getting the Monolithic furnace lining across, according to Ivon S. Pieters, general manager of the Jointless Fire Brick Co., of Chicago, has been the item of labor. It requires considerable skill to lay up fire brick and it is usually necessary to employ a skilled mason. With the Jointless lining, however, unskilled labor can be used in patching or relining a furnace. In this exhibit a section of furnace wall was shown in which Plibrico was used for the lining, giving also an idea of how the plastic lining was tied in with the outside wall. Mr. Pieters stated that business was good and that a new plant had recently been added in the East to take care of the output.

Sectional cast-iron sluice-ways are a new development, as shown in the exhibit of the Allen-Sherman-Hoff Co., of Philadelphia, where a section of one of these sluice-ways, such as is used at the new Cahokia station, attracted considerable attention. In this particular installation, the boilers are fired with powdered fuel and the fine ash drops into a hopper, passes through one of the Allen-Sherman-Hoff gates and into the sluice-way, which is about 150 ft. long, with four branches tied in to the main line. One feature of the construction is that the sluice-way is lined with renewable cast-iron plates about ¾ in. thick.

In addition this organization showed its line of ash hoppers and gates in which the important features, as pointed out by M. C. Sherman and F. B. Allen, are as follows: Cast-iron construction to resist acid water, self-supporting fire brick lining, quenchers accessible for cleaning from the outside of hopper, power-operated bottom dump, arrangement for collecting all quenching water and for its discharge to the basement. Hoppers of this type are to be installed at the new Weymouth station, at the Terre Haute station and at a new plant of the Standard Oil Co., which is now going in at Bayonne, N. J., as well as in other installations.

Last year the American Schaeffer & Budenberg Corporation, of Brooklyn, exhibited its equipment under the names of subsidiary organizations, the American Steam Gage & Valve Mfg. Co. Div. and the Schaeffer & Budenberg Mfg. Co., but recently the two organizations have been combined under one corporate name. The exhibit this year comprised the various items which go to make up the line, such as gage testers, indicating and recording thermometers, indicating and recording steam

gages, draft gages, pop-safety valves, steam traps and other similar devices.

Of special interest at the exhibit of the International Combustion Engineering Corporation this year were the air-preheater and the new Frederick stoker. Several installations of interest have been made of the plate-type preheater, one of which is the extension to the Colfax station of the Duquesne Light & Power Co.

In addition quite an extensive exhibit of the Lopulco Pulverized Fuel Burning System was shown this year. Recently the International Combustion Engineering Corporation has secured the controlling interest in the Raymond Impact Pulverizer Co. and a part of the exhibit consisted of a miniature Raymond mill with its auxiliary equipment. The fuel-burning system has been extended to include a special hollow wall furnace construction. One interesting installation of this is going in at the Cleveland Electric Illuminating Co.'s plant in connection with the installation of four 3060-hp. Stirling boilers.

Engineers are looking to the oil manufacturers as a source for information on lubrication problems, according to the Tide Water Sales Corporation, of New York. This organization showed specimens of lubricating oils and, in order to attract popular attention, the feature of the exhibit was a model of an oil derrick, tanks, and engine room, for the handling of oil, with A. R. Nelson, eastern manager of the Industrial oils work, in charge.

Ability to burn either anthracite or bituminous coal without change in the furnace was a point featured by W. L. Schultz, New York manager for the United Machine & Mfg. Co., in discussing the Harrington stoker. The exhibit consisted of one of these forced-draft, traveling-grate stokers assembled ready for operation. One of the interesting installations which gives an idea of the size in which this type of stoker may be built, is at the Cromby plant of the Philadelphia Suburban Gas & Electric Co., of Phoenixville, Pa. These Harrington stokers, which are installed under 1200-hp. Heine boilers, are 20 ft. long by 18 ft. wide.

In addition to showing the Bethlehem-Dahl System of oil burning, the Bethlehem Shipbuilding Corporation this year showed a self-contained fuel-oil handling outfit, consisting of two fuel pumps, two heaters, duplex suction and discharge strainers, pump governor, thermometers and pressure gages. The idea of this design is to eliminate any necessity for setting up the individual pieces of equipment on the job.

One of the exhibits which shows the interest that is being taken in instruments to check operating conditions was the complete showing of Foxboro instruments by the Foxboro Co., Foxboro, Mass. Several new instruments have been brought out and a number of changes have been made in the previous line in the way of minor refinements. Single, double and triple recording draft gages can be furnished with an indicating scale so that the pen-arm also acts as an indicator. A 6-in. diameter draft gage with a 12-in. scale is one of the new instruments. One improvement on the CO_2 recorder is to include the last-pass draft reading on the same chart and the instruments are also furnished with flush type mountings. Another instrument of interest was the effective-head recorder for use in hydroelectric plants, to show the difference between the head and tail-water levels. An illuminated master draft gage for air-duct pressures was another new device. This is for mounting alongside a master steam gage.

In order to give an idea of the circulation in a Bigelow-Hornsby water-tube boiler the Bigelow Co., New Haven, Conn., showed a ⅛-size model of one of these boilers fitted up with inspection windows so that the action could be observed. Fred W. Duemler, the New York manager, stated that a number of interesting installations have been made or are in progress, that business this year has been unusually good and the prospects look good for next year. One of the new installations is that for the Denver Gas & Electric Co. in the Valmont, Colo., station. Four 1332-hp. boilers are to be installed.

While the H. S. B. W.-Cochrane Corporation, of Philadelphia, exhibit was not quite as comprehensive as last year, it was thought desirable, according to C. W. Wharton, to specialize on fewer items in order to give the visitors more freedom in looking them over. For that reason, the exhibit this year was limited to the V-Notch meter which was cut away to show the flow of water over the notch, and to the Cochrane flow meters of the tilting-manometer type, the multi-port valve and the multi-port drainer.

One of the features at the exhibit of the Nash Engineering Co., of South Norwalk, Conn., was the Hytor sewage ejector. This is a new piece of apparatus as the one exhibited at the show is the first turned out in production and was on its way to Cleveland where it is to be installed. The features of this ejector are the use of a rotary compressor and the fact that the system requires no relief valve. In addition to this apparatus, the exhibit covered the Jennings centrifugal pump, and the Jennings vacuum and low-pressure boiler feed pump. R. H. Carpenter, of the New York office, was in charge.

In addition to calling attention to its regular line of equipment, the Wheeler Condenser & Engineering Co., of Carteret, N. J., exhibited the new type of hot-well pump which has recently been developed by this organization. In this pump there is no vacuum on the stuffing boxes hence no chance for air leakage into the condensate. The steam-jet air pump built by this company was also shown, R. T. Ervin, advertising manager, being in charge.

The Lunkenheimer Co., of Cincinnati, Ohio, exhibited a 12-in. cast-steel monel-mounted gate valve with Dean control which aroused much interest, as well as other valves and specialties built by the company. Work is proceeding on the development of valves for use at pressures as high as 1200 lb. but no definite announcement has been made as to when these valves will be available.

In commenting on the question of condenser tube practice, especially as regards the possible effects of corrosion, Chas. Gleason, of the Scovill Mfg. Co., of Waterbury, Conn., stated that while he did not believe slivering caused corrosion directly, he did think that it is the indirect cause of some corrosion troubles. He explained this by illustrating how carboniferous material will collect in front of and behind the sliver, which, together with salt water, sets up an electrolytic action and causes corrosion. In other words, if the sliver were not there, the probability of corrosion would be lessened. He is also a believer in relief annealing of condenser tubing but believes the annealing should be such as to leave a fine grain, as it is his opinion that a fine-grain material will, logically, stand up under service conditions. This organization is now making 500,000 lb. of

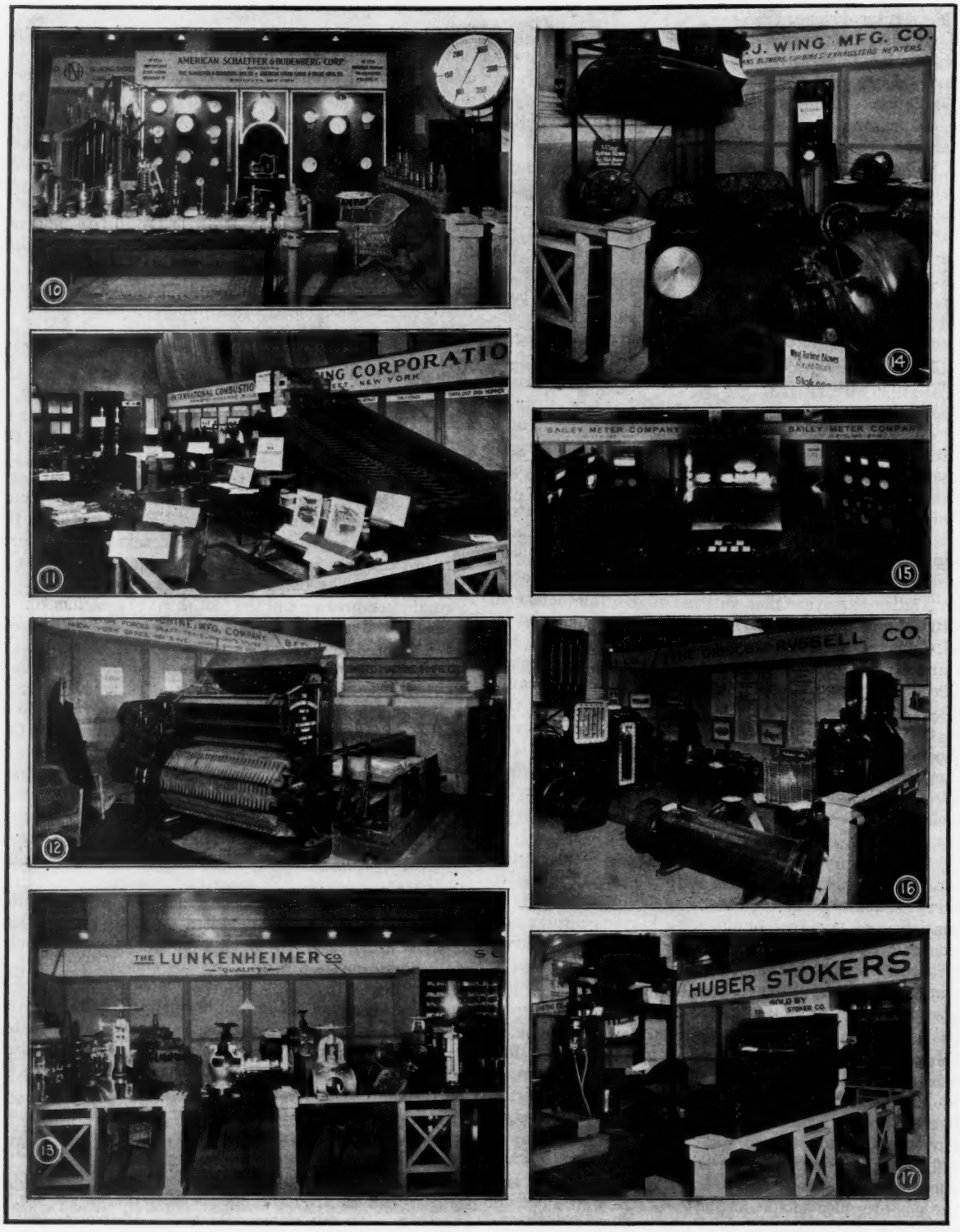

FIG. 10. MANY ITEMS OF THE AMERICAN-SCHAEFFER & BUDENBERG CORP. WERE EXHIBITED. FIG. 11. NEW FREDERICK STOKER AND THE AIR PREHEATER FEATURED BY INTERNATIONAL COMBUSTION ENGINEERING CORP. FIG. 12. HARRINGTON STOKERS WERE EXHIBITED BY UNITED MACHING AND MFG. CO. FIG. 13. CAST STEEL, MONEL MOUNTED GATE VALVE WITH ELECTRIC CONTROL SHOWN BY LUNKENHEIMER CO. FIG. 14. BLOWER EQUIPMENT FEATURED BY L. J. WING MFG. CO. FIG. 15. GLASS PIPE USED TO ILLUSTRATE ACTION OF BAILEY METER CO.'S PRODUCT. FIG. 16. NEW COOLER FOR GENERATOR AIR SHOWN BY GRISCOM-RUSSELL CO. FIG. 17. HAND STOKERS WERE EXHIBITED BY FLYNN & EMRICH CO.

condenser tubing a month. One of the interesting points mentioned was the fact that the condenser tubes for the new Trenton Channel plant of the Detroit Edison Co. are to be 24 ft. long.

Turbines for driving pumps and equipped with regulating governors were shown by the L. J. Wing Mfg. Co., of New York City. Turbine-driven blowers for underfeed and forced-draft chain-grate stokers were also exhibited. In addition V. H. Carples, secretary, called attention to the motor-driven blowers with automatic regulating equipment for low-pressure heating plants, as well as the unit heater for industrial heating.

When you think of a safety valve, you think of it as a piece of equipment that would not ordinarily be so heavy that it would be difficult for one man to lift it. You would think that until you had seen the safety valves which have been designed for 1500 lb. pressure by the Manning, Maxwell & Moore Co., of New York City. These valves have an exposed spring and a toggle joint construction, the spring itself being made out of 1 in. by 1 in. stock.

Some minor changes have been made in the Mono CO_2 and combustible gas recorders which are built by the C. J. Tagliabue Mfg. Co., of Brooklyn, N. Y. F. H. Harger, combustion engineer, pointed out that the lower shelf which carries the analyzing mechanism can be swung out so that it is accessible and that a light has been placed in the case for illuminating the chart. One of the new devices brought out by this organization is the Tag-Hespe red-reading-column thermometer.

As was the case last year, the American Arch Co., of New York City, exhibited its suspended arch construction by showing a section of a furnace. Several of the features pointed out by H. A. Mannshardt were that all of the steel is out of the heat zone and that floating skews and springs allow for expansion. Although this organization has done quite a bit of work in the stationary field it is particularly well known in the locomotive field as some 65,000 locomotives have been equipped with American arches.

In showing the automatic skip-hoist control the Otis Elevator Co., of New York City, deviated from the exhibit of last year as at that time the Micro elevator drive was shown. The skip-hoist controller is suitable for use with hoists handling coal and is also extensively used in steel-mill work for blast furnaces. Another feature of this exhibit, as pointed out by W. H. Daly, was a model of the Otis escalator.

When it is considered that some 82,000,000 hp. of boilers have been equipped with Elesco superheaters some idea may be had of the amount of business which is done by the Superheater Co., of New York City, in the power plant field. This, of course, does not include superheaters for locomotives. L. H. A. Weaver, publicity manager, stated that one of the interesting jobs which they had under way was that at the new plant, using pulverized fuel, which is now being built by the St. Paul Gas Light Co. Models of superheaters used in stationary practice and a sample board showing how the forged return bends are made were also features of the exhibit. In addition, stereopticon views of various installations and arrangements were shown.

One of the exhibits which attracted much attention at the show was that of the Bailey Meter Co., of Cleveland, Ohio, in which glass pipe and fittings were used to show how water flows through a pipe, particularly when it is swirling. In order to secure the swirling effect, an agitating device was used at the entrance of the flow and air was blown into the glass line at the same time. In this way, the air bubbles indicated the swirling condition and how far this was carried through the pipe line. An orifice at one section of the glass pipe line was connected with vertical glass tubes to show the variation of pressure and the Venturi action of the orifice.

New equipment which was featured by the Bailey organization was the geared type of centrifugal tachometer which is used for such applications as underfeed stokers. The gear train speeds up the action of the whirling tube which creates the vacuum in this type of instrument. An improvement which has been made in the line of tachometers of this general vacuum type is the compensating feature. A heating element has been introduced in the case so that the air temperature may be maintained constant. This increases the accuracy, as wide variations in the temperature of the air, causing change in density, would affect the accuracy by as much as 2 per cent without this compensating feature.

In addition the Bailey organization showed its line of multi-pointed gages and boiler meters, coal meter, air and gas meters and special types of boiler-meter panels. W. E. East, Chicago district manager, explained the exhibit.

Pipe fittings of all kinds, steam specialties and fabricated pipe were featured by the Crane Co., of Chicago, Ill. Crane cast-steel valves, electrically operated, for steam pressures up to 1500 lb. were also exhibited by W. L. Oswald and G. E. Baker in charge.

Two types of ash hoppers were shown by the Beaumont Mfg. Co., of Philadelphia, Pa. As explained by W. J. Burnett, secretary, one of these is a gravity ash hopper, with hand-operated pivoted ash gates, recommended for discharging to small ash cars and larries. The gates are counter-balanced and the ash hopper is provided with a drainage system. Vitrified paving brick is used for lining. The other Beaumont ash hopper is the same so far as the hopper design is concerned, but a power-operated cast-iron ash gate is used, which operates on self-cleaning T rails. The drain troughs are protected against filling up with ash as the opening into the trough is only about $\frac{1}{8}$ in. so that only fine ash is allowed to pass which can be literally carried off in the drain water.

Coal handling was the feature of the R. H. Beaumont & Co. exhibit. This company is a separate organization from the Beaumont Mfg. Co. although the same interests control the two concerns. P. K. Reed, Chicago district manager, explained the exhibit, which consisted of a model of a coal-handling plant. In this system, coal is dropped by rail into a hopper, automatically loaded into a skip-hoist by a Simplex loader and discharged from the skip hoist, either into the bunker or to a pile alongside the railroad track. From this pile the coal is spread by cable drag scrapers, which also reclaim the coal by pulling it up to the hopper into which it was originally dumped. All of this was in model form, although the skip-hoist was actuated by a full size winding machine and controlled by a Cutler-Hammer full automatic direct-current control panel, having accelerating, slowdown and pause features. The cable scraper was operated by a $\frac{1}{8}$ size winding machine.

This year the Griscom-Russell Co., of New York City, exhibited the U-fin generator air cooler as a feature. This cooler utilizes the condensate for cooling the generator air, at the same time raising the temperature of the condensate about 10 deg. as it passes to the feed heating system, thereby taking advantage of the heat which otherwise would be wasted and cooling the generator air. In addition, the company showed the Reilly evaporator, feed-water heater and fuel-oil heater, as well as the steam-jet air ejector. Stanley Brown, who handles the public utility work in the East, described the equipment.

One new development of the Reading Steel Casting Co., of Bridgeport, Conn., is the line of brass globe valves for 250 lb. pressure. Cast-steel gate valves for pressures from 250 to 800 lb., with electric control, were also shown as a part of the exhibit. According to W. H. Cashin, New England manager, the line of cast-steel fittings will be designed for any high pressures which may be needed.

W. A. P. Penninger, engineer for the Peabody Engineering Corporation, of New York City, stated that considerable interest had been manifested in oil-burning equipment at the show. This organization featured its wide-range mechanical burner with a bypass, which permits regulating from a banked fire to maximum load without changing the burner tip.

Huber hand stokers, overhead hoppers and sectional boiler fronts were shown by the Flynn & Emrich Co., of Baltimore, Md. One of the Huber stokers was set up and shown in action at the exhibit. Chas. J. Huber, mechanical engineer, pointed out some of the details of the construction used.

Stirling boiler-feed system, lifting traps, vacuum traps, and separating traps made up a part of the exhibit of the Stirling Engineering & Mfg. Co., of Hyde Park, Mass. C. J. Stebbins, sales manager, and C. C. Tracy, general manager, called attention to the working model of the Stirling boiler-feed system.

During the last year considerable thought has been given to the subject of recording the combustible in flue gases in order to reduce the possible loss to a minimum. The exhibit of the Uehling Instrument Co., Patterson, N. J., at which its new combustible recorder was shown, attracted considerable interest. This recorder depends for its action on two small platinum tubes which are connected in series, with a connection to the recorder taken off the line between them. The tubes are heated by the passage of an electric current and, as the sample of flue gas is drawn through by the standard suction of the CO_2 recorder, the combustible in the gas is burned out in the first tube. Since this rarefies the air, it creates a difference in the suction at the point where the recorder connection is made, therefore gives an indication which may be calibrated in terms of per cent combustible.

One change in the line of the Coppus Engineering Corporation, of Worcester, Mass., has been the addition of a motor-driven boiler feed pump using the same unit construction as the turbine-driven type. That is, the motor and the pump are tied together with only two bearings. R. H. Harper, who described the exhibit, stated that one of their interesting installations of blowers was in the new Iron Mountain plant of the Ford Motor Co.

Connery's expansion stiffener construction for smoke flues and air ducts was again exhibited this year, by Connery & Co., of Philadelphia, who showed a section of the breeching which is to be installed at the new Bayonne plant of the Standard Oil Co. Installations of this construction which are of interest are those at the Cahokia station, at the Philo plant and the Colfax Extension.

Among the improvements made by the Lewis M. Ellison Co., of Chicago is the use of a sliding scale of white enamel on inclined draft gages. Besides being easy to read, this permits a zero adjustment. Additions to the line of instruments are the three and four-tube inclined draft gages, and a new portable gage with leveling attachment. For the vertical draft gages a paper scale is used in addition to the permanent scale. This paper scale can be marked in colors to show the correct draft for the various zones, as well as the duct pressure. Mr. Ellison stated that business was a little spotty but good for the year.

Valves, fittings and tools for steam, water, gas, oil and air, together with Walworth Kewanee unions and Walworth piping, were shown by the Walworth Mfg. Co., of Boston, Mass. F. M. Churchill, assistant publicity manager, was at the exhibit. One feature which attracted considerable attention was the first Stillson wrench, made by Dan Stillson more than 50 yr. ago.

In a vertical non-return valve, which was shown by the Edward Valve & Mfg. Co., of East Chicago, Ind., free flow through the valve is facilitated and one joint less is required in the superheat leads from the boiler to the steam main. There was also the complete line of drop forged body and bonnet valves, and a new drumhead stop-and-check valve for feed-water lines, to be located next to the boiler water inlet. The Edward 680-line of forged steel valves are fitted with monel metal.

According to L. R. Merritt, New York representative of the Springfield Boiler Co., of Springfield, Ill., business is good with that organization. A number of interesting installations are being made, including three additional boilers for Hell Gate, and six at the Sherman Creek plant. The new plant of the Peoria Light and Power Co. will have four 1500-hp. boilers designed for 400 lb. pressure and the Virginian Railway Co. is installing five boilers of 1500 hp. each, at 350 lb. pressure.

New applications for temperature regulators are continually being found, so that the business of the Sarco Co., Inc., of New York City is up and going, according to E. J. Ritchie, sales manager. Several new devices have been added to the line, including a 1-in. radiator trap for use on heating stacks and main line drips. Another device is a dead-end service valve for small hot-water tanks where leakage through ordinary piston valves is so great as to affect the operating service of the regulator. Control of temperature for fuel oil as it goes to the burners is becoming an important item. As efficient atomization of oil depends on the temperature, proper regulation is of considerable value to the power plant.

Higher pressures and temperatures are subjects of extremely great importance to the valve manufacturers and, according to C. H. Maher, sales manager for the Chapman Valve Mfg. Co., Indian Orchard, Mass., this organization is continuing its research work to determine the effects of high temperatures on the metallurgical properties of metals. The organization is also taking

an active part in the standardization work which will lead eventually to getting the high-pressure valves and fittings on a definite basis.

One improvement which has been made in the Chapman motor-operated valves is the addition of a white light to the control stations. This white light is on at all times when the valve is in gear but, as soon as valve is thrown into the hand-operated position, the light goes out at all of the stations, regardless of how remote they may be from the valve itself. This gives the operator an idea as to whether the valve is in working condition. When the valve is open, a red light shows and, when closed, a green light indicates the fact.

According to A. T. Smith, of the Permutit Co., New York, business in the Permutit water softener and filter has been good in 1923, in fact about 30 per cent better than in 1922. This exhibit comprised a model of a softener and filter, a collection of boiler tube sections, showing the effects of scale, and a number of photographs of recent installations.

That the Pittsburgh Valve Foundry & Construction Co., Pittsburgh, Pa., is interested in higher pressures was shown by its exhibit in which a 500-lb. cast-steel gate valve with monel-metal mountings, machined guides and double discs was featured. The organization, according to Geo. Stuart, chief engineer, is prepared to furnish valves for any of the higher pressures according to demand. Another valve which was shown was a 350-lb. Atwood motor-operated gate-valve with Dean control. The method of making up a welded header, as shown last year, was repeated this year.

Condenser tubing as made by the Chase Metal Works, of Waterbury, Conn., with various samples of metals and test specimens twisted in various shapes to show the quality, were on exhibit. H. C. Ashworth, of the Chase organization, stated that one of the interesting condenser-tube jobs which had been handled recently was that of the new Devon plant of the Connecticut Light & Power Co., at Devon, Conn.

Several improvements and additions have been made to the line of the Republic Flow Meters Co., of Chicago, Ill. Mechanically-operated draft-indicating and recording instruments and a new type low-priced, electrically-operated boiler meter were two of the additions to the line which were shown. The new boiler meter is not quite as accurate although it is guaranteed for 3 per cent but, according to S. A. Reinhardt, Philadelphia manager, there has been a demand for a cheaper instrument where great accuracy is not required. A 24-in. illuminated load indicator is also a new development. This instrument is electrically operated and may be plugged in on any of the electrically-operated boiler meters. The regular line of CO_2 meters and electrically-operated flow meters was also shown.

The exhibit of the Graver Corporation of East Chicago, Indiana, was quite similar to that of last year. A large chart was shown from which a good idea could be had of the method of operation of a Graver hot-process softener. L. H. Welling, of the New York office, stated that business had been good during the past year.

Centrifugal and reciprocating boiler-feed pumps were the main features in the exhibit of the M. T. Davidson Co., of New York City. A 1-in. side-suction pump was in actual operation and a section of the open-front type reciprocating boiler feed pump was shown by John Lowe, sales manager for the company.

While looking over the exhibit of the Yarnall-Waring Co., of Philadelphia, Mr. Yarnall stated that the company was pushing the spray pond business and pointed out the line of involute nozzles, complete from ½-in. to 2-in. The double nozzles are built in sizes from 2 to 2½ in. One of the interesting spray pond installations which was recently put in is at Fort Worth, Texas, for the Fort Worth Power and Light Co. This pond, one of the largest in the world, has a capacity of 60,000 gal. per min.

A. W. France, of the France Packing Co., Philadelphia, Pa., stated that the packing business had been about 30 per cent better in 1923 than in 1922. High-speed compressors in the refrigerating industry have added to the packing problem and the demand for metallic packing in this service has been quite active.

Three-way operating valves with the B & O protected seat were of particular interest at the exhibit of the Homestead Valve Mfg. Co., Homestead, Pa. E. E. Jones, eastern sales manager, stated that the company bought out the B & O Protected Seat Valve Co. in 1923 and is now building this valve as a part of its line. The protected-seat valve has been found to give especially good results in throttling service because of the fact that wire drawing does not take place on the seat itself. The quarter-turn lubricating valve was also shown.

Suspended arches, air-cooled side wall blocks and rear combustion arches were features of the exhibit of Waite & Davey Co., Inc., Long Island City, N. Y. Frank H. Waite, president of the company, said that tests have shown that the preheating effect on the air is such that, when air is drawn in at about 70 deg. and passed through the side walls, it is discharged into the combustion air duct at about 450 to 500 deg. F.

Curtis steam specialties, including the new type G regulator, were shown at the exhibit of the Julian d'Este Co., of Boston, Mass. This company was represented by Boig & Hill, Inc., New York City. The regulator is of the auxiliary operated type, having a secondary valve operating the main valve. The main valve is single seated, spring loaded and is operated by a piston.

As last year, the master steam gage of the Ashton Valve Co., Boston, was the main feature of the exhibit. According to Mr. Ashton, business has been good with this master steam gage and the casing has also been sold to a number of other manufacturers for use on load indicators and other purposes. The dead-weight gage tester with a ratio of 5 to 1, or 20 to 1, was also shown, this double ratio facilitating high-pressure testing. In addition, the regular line of safety valves, relief valves, gages and whistles was shown. Mr. Ashton stated that business had dropped off slightly in the latter half of the year but he thought the decline was partly seasonal.

Drainage control, in which the general scheme used for the S-C feed-water regulating system has been applied to draining receiver and separator tanks, was one of the interesting features of the exhibit of the S-C Regulator Mfg. Co., Fostoria, Ohio. There was also the regular line of feed-water regulators and pump governors for pressures up to 1200 lb., with H. S. Fraser, New York manager, in charge of the exhibit.

In order to make the work of tube cleaning easier for the operator, the Roto Co., of Hartford, Conn., has

added a shut-off valve to its tube cleaner. This valve, as explained by W. R. Van Northwick, general manager of the company, is placed just back of the cleaner so that, when changing the cleaner from one tube to another, it is possible to shut off the action by a turn of the valve. One of the new types of cleaning head is designed so that each cutter moves out radially the same distance as the other two cutters. In other words, the motion of each cutter arm is synchronized with the other two.

Development of remote boiler-water-level indicators has been active recently and the Bristol Co., of Waterbury, Conn., has approached its work on such instruments from an unusual angle. In the instrument which has been developed by this organization, a rod about 18 in. long, on which is mounted a number of thermocouple elements, is placed in any of the standard type of safety-alarm water columns. As the water level drops, the height of the water is indicated by the temperature difference between the water and the steam

FIG. 18. WIDE VARIETY OF TOOLS AND FITTINGS SHOWN BY WALWORTH MFG. CO. FIG. 19. VALVES AND WELDED HEADERS COMPRISED EXHIBIT OF PITTSBURGH VALVE, FOUNDRY & CONSTRUCTION CO. FIG. 20. CONDENSER TUBING WAS SHOWN BY THE CHASE METAL WORKS. FIG. 21. ELECTRIC FLOW METERS IN OPERATION WERE THE FEATURE OF REPUBLIC FLOW METERS CO. EXHIBIT. FIG. 22. MASTER STEAM GAGE ATTRACTED ATTENTION AT ASHTON VALVE CO. EXHIBIT. FIG. 23. INSULATING MATERIAL WAS FEATURED AT EXHIBIT OF CELITE PRODUCTS CO.

Gaskets of the copper and asbestos type were shown by the Metallo Gasket Co., of New Brunswick, N. J. Zeno Schultes, president, and P. L. Rhodes, sales manager, discussed the exhibit and stated that 1923 business in gaskets had been good.

and the reading is indicated either on an indicating type of electrical instrument similar to a volt-meter or the action may be permanently recorded on a recording type of instrument. Thos. S. Derr, of the engineering section, who developed this type of instrument, stated

that it had been found to be quite accurate and that it offered the additional advantage that it could be placed in any position on the boiler room instrument panel or, if necessary, in the chief engineer's office or the main control room of the station. In addition, the regular line of Bristol recording pressure and vacuum gages, recording thermometers, time recorders, tachometers, etc., were shown.

The veneer furnace lining, which is made up of steel mixture blocks, was a feature to which attention was called by A. L. Keeler, sales manager of the McLeod & Henry Co., of Troy, N. Y. This type of furnace lining construction permits placing the fire brick as a permanent part of the wall construction while the veneer lining may be renewed as it is burned out. This tends to reduce the maintenance cost for a furnace, as the veneer lining is only about 4 in. thick, whereas with straight fire brick construction a 9 in. wall is required and the entire wall must usually be rebuilt.

In the exhibit of the Dearborn Chemical Co., of Chicago, the quantity of scale-forming solids in 100 gal. of water was shown for water supplies in various parts of the country. Specimens of scale formations on sections of boiler tubes, showing the corrosive action of various waters also made up a part of the exhibit. The method of treating boiler water to reduce scale troubles was explained by Grant W. Spear, eastern manager for the company.

Automatic valve specialties, including pump governors, pressure regulators, and such devices as hydraulic reducing valves, automatic non-return stop valves and automatic stop and check valves, formed the exhibit of the Foster Engineering Co., Newark, N. J., under the supervision of Chas. A. Ollson, general manager.

A new model of the Hays CO_2 recorder was shown this year by Paul B. Huyette Co., Inc., Philadelphia. In addition, Mr. Huyette called attention to the water gages, gage cocks, safety water columns and traps, Ajax damper regulator, control valves, etc., which are a part of the line carried by this organization.

In showing the heat-insulating properties of Sil-O-Cel, a blow torch was used to give an idea of the heat penetration. Although the flame of the blow torch was directed on the brick, the opposite side showed no increase in temperature even when it was exposed to the flame for several hours. The exhibit was made up of the various Sil-O-Cel products such as the powder and the cements and was under the general direction of E. S. Crosby, general sales manager.

An exhibit of oil burning equipment was made by the W. N. Best Corporation, of New York City, in which its air and steam-atomizing type of burner was shown. This exhibit was in charge of E. F. Hammond and F. W. Conlin, of the Best organization.

As a means of showing the operation of its line of steam traps, the Bundy Steam Trap Co., of Nashua, N. H., used a boiler carrying an air pressure of 35 lb. This boiler was fed by a ¾-in. return trap with the overflow discharging into a tank trap set on the floor about 10 ft. from the boiler. This trap discharged into an open tank about 8 ft. above. From the tank the water was fed by gravity to a three-valve pumping trap about half way between the open tank and the floor. This pumping trap pumped the water to a small receiver placed above the boiler return trap whence it was fed by gravity to the return trap which in turn delivered it to the boiler. W. W. Booth, New York manager, was at the exhibit.

James T. Gordon Co., of New York, represented the Andale Engineering Co., the Union Iron Works, Frederick Iron & Steel Co., and the W. H. Nicholson Co. The exhibit was made up of Frederick centrifugal pumps, ash conveyors and ash handling equipment, Andale duplex strainers, photographs of the Union Iron Works boilers and the Wyoming steam traps, which are a part of the Nicholson line.

Keystone manifold safety lubricators were the main feature of the exhibit of the Keystone Lubricating Co., of Philadelphia, Pa. This lubricator consists of a cylinder having a hand-wheel operated piston and pipes connecting to the various bearings which are to be lubricated. Pressure is applied by the piston and, by opening up the valves in the proper pipe lines, it is possible to lubricate the bearings desired. This type of lubricator is especially adaptable to bearings which are rather inaccessible. The line of Keystone greases was also shown.

Power plant specialties such as pump governors, pressure regulators, steam traps, regulating valves and floats were shown by the Fisher-Governor Co. of Marshalltown, Iowa. J. H. Fisher, president of the company, was in attendance at the exhibit part of the time.

Mono boiler baffles, and Flame Brand high-temperature cement were featured at the exhibit of the King Refractories Co., of New York City. S. C. Smith and T. J. Bulkley, of the King organization, looked after the company's interests at the show.

Last year Gillis & Geoghegan, of New York, showed one of its systems for the removal of ash from basement plants. This year a similar set up was used in which the working of this type of equipment was shown. Chas. E. Prout of the company explained the operation.

In commenting on the exhibit of the Morse Drydock & Repair Co., D. V. Stratton pointed out that two parts of the Morse service were covered which were not quite as well known as the oil-burning equipment. Turbine balancing and Diesel engine installation and repair work are parts of the Morse service and these were illustrated by the aid of photographs. Mechanical and steam-atomizing burners and air registers were included in the exhibit.

Several installations are now being made of the Howden-Ljungstrom air preheater which is a Swedish development, now built and marketed in this country by James Howden & Co. of America, Inc., Wellsville, N. Y. The International Paper Co. has installed two units at Belden, N. H., six at Piercefield, N. Y., and six are also to go in at its Niagara Falls plant. C. W. Hume, vice-president of the company, stated that business in their preheaters was active, with a large number of prospects in view.

According to W. S. Cannon, of Henry Vogt Machine Co., of Louisville, Kentucky, this organization will be on hand for next year's show. This year was their first experience and they considered it quite satisfactory. A part of the line of drop-forged fittings, and steel valves, as well as photographs of the Vogt boilers were shown.

Falk herringbone gears, the Falk Diesel engine and a new flexible coupling were featured at the exhibit of the Falk Corporation, of Milwaukee, Wis. The line of Diesel engines manufactured by this company runs up

into large units, one which is used for operating their shop equipment being rated at 2500 brake hp. John Jurgensen was in charge of the exhibit.

In order to show the line of leather belting which is built by the Graton & Knight Mfg. Co., of Worcester, Mass., this organization had an exhibit of a rather complex system of line shafting with leather belts operating at various angles and twists. C. O. Streeter, mechanical engineer, was in charge of the exhibit.

One of the exhibits of general interest was that of the S. K. F. industries, New York City, where several things attracted popular attention. One of these was a wheel, mounted in ball bearings, which would run from 5 to 7 hr. under its own momentum, and would rotate if a quarter were placed on one of the spokes.

A display of traps which attracted attention was that of the Armstrong Machine Works of Three Rivers, Mich. Armstrong steam traps, including a glass model of one operating under pressure, were shown. O. E. Ulrich was in charge of the exhibit.

Gifford-Wood Co. of Hudson, N. Y., illustrated its line of coal-handling equipment by showing a model of a coal bunker and conveying equipment. Photographs were also shown of ice-handling machinery and portable belt conveyors.

Cleaning of condenser tubes by means of rubber plugs has been brought out by Manion & Arthur Co., of Perth Amboy, N. J. These plugs are made in several sizes and are blown through the tubes by compressed air at pressures from 20 to 100 lb. The drain

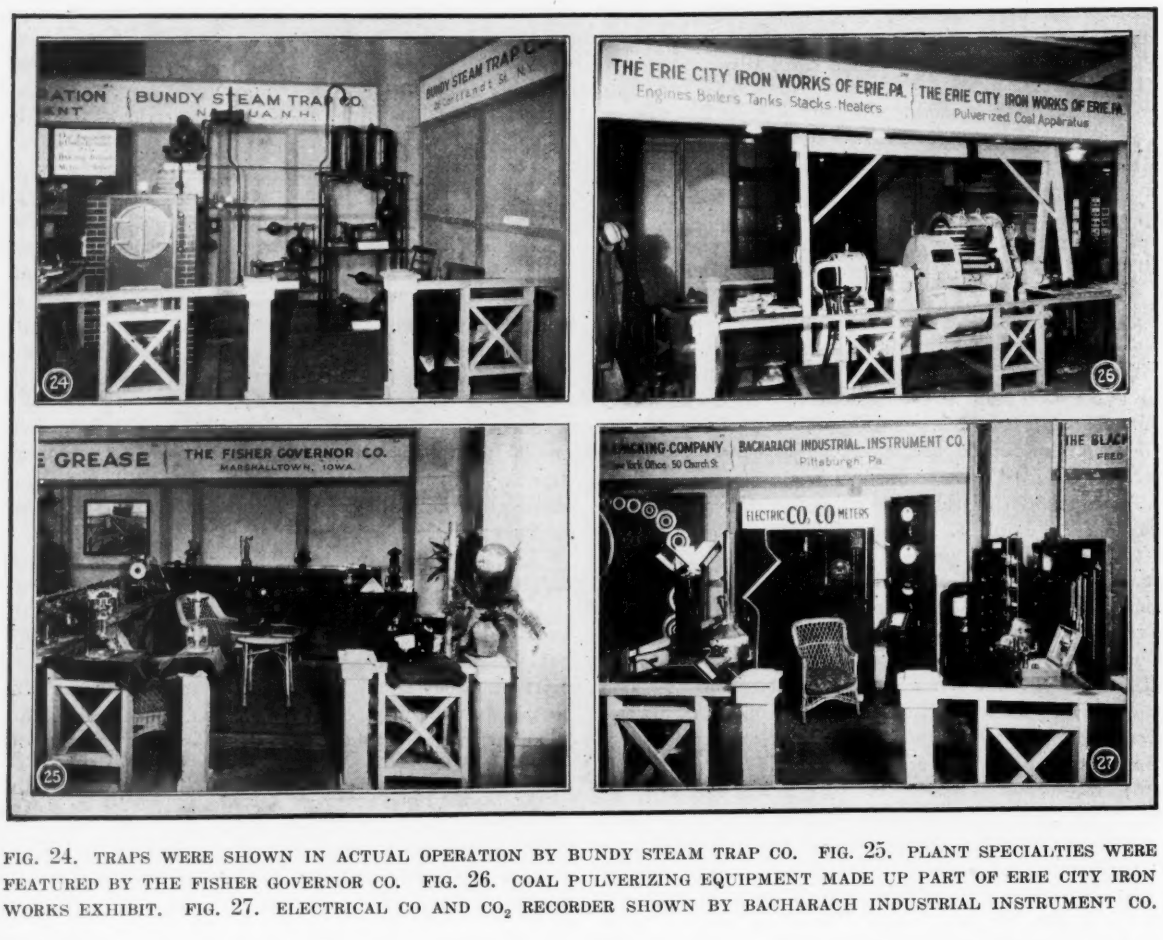

FIG. 24. TRAPS WERE SHOWN IN ACTUAL OPERATION BY BUNDY STEAM TRAP CO. FIG. 25. PLANT SPECIALTIES WERE FEATURED BY THE FISHER GOVERNOR CO. FIG. 26. COAL PULVERIZING EQUIPMENT MADE UP PART OF ERIE CITY IRON WORKS EXHIBIT. FIG. 27. ELECTRICAL CO AND CO_2 RECORDER SHOWN BY BACHARACH INDUSTRIAL INSTRUMENT CO.

A 1/20-hp. motor was used to drive a heavy line shaft some 20 ft. in length to illustrate the lack of friction in ball-bearing-type shaft bearings. D. W. McAllen was in charge of the exhibits.

Impact pulverizers were shown by the Aero Pulverizer Co., New York. According to W. W. Clinedinst, field engineer, the action of this pulverizer is dependent on a series of heavy cast-iron paddles which strike the coal. Improvements in the pulverizer are the adoption of split bearings, a side dump iron separator and the use of a heavier paddle construction. Several interesting installations have been made, one of which is at the Ohio Public Service Co. plant at Mansfield, Ohio.

line is covered with a screen so that the plugs are recovered and used again. Martin Manion stated that plugs of this type could be used from 400 to 2500 times before they were worn out.

The line of pulverizing equipment made by the Erie City Iron Works, of Erie, Pa., was illustrated by a complete pulverizer of the impact type. These pulverizers are units in themselves, as the coal is fed directly from the pulverizer to the burners. J. I. Cramer, field engineer, stated that a number of installations are being made.

Oil burners were shown by the Coen Co., of New York City, as well as its line of strainers, fuel-oil heaters

and air registers. According to F. S. Harper, this concern has been doing a lot of business in the marine field but has only recently taken up stationary plant work.

Single-roll coal crushers and Bradford breakers were shown by the Pennsylvania Crusher Co., of Philadelphia, Pa., the exhibit including a section of the screen used in the breaker, as well as photographs of various installations.

One new development of the Everlasting Valve Co. of Jersey City, N. J., has been the new shockless pendulum type of stop valve. Another was a valve, which can be locked in the open position, for use between the water column and the boiler. Other lines of Everlasting valves for blowoff and other service were also shown.

High temperature cements, granular refractories and the various methods of application were shown by the Keystone Refractories Co., of New York, of which F. W. Reisman is president.

Steam-jet ash conveyors, built by the Girtanner Engineering Corporation, New York, were shown as a part of the exhibit of this company. In addition, the Perfection grate, which is handled by this organization in the New York territory, was on exhibition. A. Girtanner, president of the company, stated that business had been particularly good this year.

In order to show its type of boiler construction, the Walsh & Weidener Boiler Co., of Chattanooga, Tenn., used a model of its cross-drum water-tube boiler, also a section of a full size header. W. E. Weigel was in charge of this exhibit.

One of the developments of the Crosby Steam Gauge & Valve Co. has been an all monel-metal valve for 500 lb. pressure and 900 deg. F. Valves of this metal are of the screwed type and are made in sizes up to 2½ in. A line of cast-steel globe and angle valves for the same range of pressures and temperatures has also been brought out. These cast-steel valves are monel trimmed. The regular line of safety valves, indicators, steam gages and other appliances was shown.

At the exhibit of Warren Webster & Co., of Camden, N. J., the new Webster boiler-return trap, for returning water to the boiler under pressure, was shown. Another feature of interest, as pointed out by W. C. Schueler, was the wrought-iron feed-water heater. This wrought-iron casing is comparatively recent, although the line of heaters in cast-iron casing has been built for many years. The Webster modulation valve for heating service was also shown.

Metal gaskets were featured by the Goetze Gasket & Packing Co., of New Brunswick, N. J., the exhibit being in charge of King & Shepherd Co., who are the New York representatives of the Goetze organization. This type of gasket is made of corrugated copper, in which asbestos rings are imbedded.

Steam pumps of the Duplex type of an unusually heavy construction were shown by the Union Steam Pump Sales Co. of Battle Creek, Michigan. R. W. Friedman, manager, explained that this pump has a number of features such as an outside positive valve motion, which may be adjusted, removable liners, and pre-admission ports. Centrifugal pumps were also shown as a part of the regular line.

The interest in CO and CO_2 recorders at this year's show was quite active, and the electrical instruments of this type shown by the Bacharach Industrial Instrument Co., of Pittsburgh, Pa., attracted marked attention. These instruments work on the principle that the heat conductivity of gases varies and advantage is taken of this fact by heating wires in the presence of the flue gas in one chamber and of ordinary air in another. Since the radiation is greater in one case than in the other, the temperatures of the wires are different, hence the deflection of a galvanometer will show the percentage of CO_2. The same general idea is used for the measurement of CO. H. Bacharach, head of the company, pointed out that the regular line of optical pyrometers, manometers, universal draft gages and integrating indicators was on exhibit.

This year the Blackburn-Smith Corporation, New York, featured the multi-duct strainer in which it is possible to clean one basket while two others are in service. Strainers of this type are suitable for use with water and have also been used for oil and chemicals. I. H. Kaufman said that, since their announcement some months ago, business had been particularly good in these strainers. In addition, the feed-water filter and grease extractor was shown, this being one of the pioneer terry-cloth filters used in stationary practice. Also, a sewage ejector and a vacuum trap were shown by this organization.

In addition to the line of oil storage tanks and pumping equipment for handling lubricating oils and gasoline, the Wayne Tank & Pump Co., of Ft. Wayne, Ind., had a model of its Borromite water-softening equipment. R. F. Roberts said that interest had been quite active in the water-softening process and that the company expected to do a big business in this line of work.

A line of equipment for handling and burning pulverized coal which attracted interest was that of the Fuller-Lehigh Co., of Fullerton, Pa. In this exhibit, a model of a 6-in. unit, which pumps pulverized coal through a 5-in. line for a distance of more than a mile, was shown. Flour was used instead of pulverized coal to show the action in the model system, which included one of the electro-pneumatic distributing valves, together with the automatic bin signals. Models of vertical and horizontal burners, the new vertical dryer and the impact mill were also exhibited. According to H. A. Reichenbach, advertising manager, the rights have just been acquired on a unit type of impact pulverizer and this will, in the future, be built as a part of the line. One of the interesting installations of this unit will be at the Sherman Creek Station of the United Electric Light & Power Co., of New York City. Several types of coal burning systems are to be installed at this station for testing and experimental purposes.

At the exhibit of the Marion Machine Foundry & Supply Co., of Marion, Ind., the new Marion balanced-head soot blower was shown. Due to the type of construction used, it is claimed that this type of soot-blower head reduces the end thrust on the unit. The combination hand and hopper-feed stoker and Marion master grates were also a part of the exhibit.

Internal combustion engines and refrigeration units were shown by the Climax Engineering Co., of Clinton, Iowa. Photographs of installations showing the adaptability of these four and six-cylinder gasoline engines to various power installations were also a feature of the exhibit.

The exhibit of the "X" Laboratories of New York City showed the X boiler liquid for sealing leaks, J. S. Shirley, advertising manager, being in charge.

Fire brick in special shapes, high-temperature cement and fire clay made up the exhibit of the A. P. Green Fire Brick Co., of Mexico, Mo., in charge of J. B. Arthur.

One of the new developments of the Liptak Fire Brick Arch Co., of Chicago, during the last year has been the interlocking furnace wall construction. Several installations of this construction have been made, one of which is at the Pine Grove, Pennsylvania, Station, which was designed by the J. G. White Engineering Corporation. The new Devon plant of the Connecticut Light & Power Co. will also use this type of construction. C. E. Sharp, general manager of the company, stated that interest had been quite active in the interlocking wall construction as well as the suspended arch. A section of the single and double-suspension arch was also shown at the exhibit.

Several minor improvements have been made in the multiple retort under-feed stoker which is built by the Detroit Stoker Co. R. L. Beers, mechanical engineer, pointed out that the most important of these was in the adjustment for controlling the stroke of the pusher rod. This adjustment has been placed at the connecting rod so that it can be controlled simply by changing the location of a pin in an adjustment block. The device for changing the stroke of the ram has also been modified and high-pressure grease lubrication has been adopted for the stoker.

Regulation of feed water by means of the Stets

FIG. 28. WATER SOFTENING EQUIPMENT SHOWN BY WAYNE TANK & PUMP CO. FIG. 29. MODEL OF A PULVERIZED COAL TRANSPORT SYSTEM FEATURED FULLER-LEHIGH EXHIBIT. FIG. 30. SUSPENDED ARCHES AND FURNACE WALL CONSTRUCTION SHOWN BY LIPTAK FIRE BRICK ARCH CO. FIG. 31. TUBE CLEANING SYSTEM AS INSTALLED BY MARION MACHINE FOUNDRY & SUPPLY CO. FIG. 32. MULTIPLE RETORT UNDERFEED STOKER IN OPERATION AS PART OF DETROIT STOKER CO. EXHIBIT

boiler feed controller was shown by the Williams Gauge Co., of Pittsburgh, Pa.; also the Williams high and low-water alarm columns and water gages.

Boiler-feed metering devices actuated by venturi tubes were shown by the Simplex Valve & Meter Co., of Philadelphia, Pa. One of the interesting installations of this equipment is in the Colfax plant of the Du-Quesne Light & Power Co. The exhibit was in charge of W. K. Sowdon, New York manager.

At the exhibit of the Elliott Co., of Pittsburgh, the Elliott Deaerator was exhibited. This deaerator removes the air from the feed water by evaporation and re-condensing. In going over the recent installations of interest, C. L. Brown, New York manager, stated that the new Kearny plant of the Western Electric Co. at Kearny, N. J., will use deaerators of this type. The Western Electric Co. is building a new lead-covered-cable factory at this location. Another installation is the Valmont, Colo., station of the Denver Gas & Electric Co. In addition to deaerators the Elliott organization showed its air ejectors, oil strainers, non-return and blowoff valves and Liberty and Lagonda tube cleaners.

Photographs of furnaces in which Maphite has been used for re-lining and for repair work were shown by the Maphite Corporation, of Chicago. This refractory is made up of high-temperature cement, by use of which in the furnace it is said that air filtration is stopped and a brick and tile furnace made monolithic. E. C. Brisbane had charge of the exhibit.

Corrosion-preventive solutions were shown at the exhibit of the Wales-Dove-Hermiston Corporation, of New York. These solutions are marketed under the trade name of Bitumastic and Hermastic, and are used for painting coal bunkers, the interior of boilers and condensers and other like purposes.

One of the devices to which particular attention was called at the exhibit of the Armstrong Mfg. Co., of Bridgeport, Conn., was the ratchet attachment to fit the ordinary Armstrong die stock. In addition the line of nipple chucks was shown.

A line of Venturi meters was shown by the Builders Iron Foundry of Providence, R. I., with a Venturi meter in full operation as a part of the exhibit.

At the exhibit of the Dampney Co. of America, Boston, Mass., "Apexior" coatings for metal surfaces were shown. It is claimed that corrosion on the internal surfaces of water tube boilers, steel-tube economizers, condensers, etc., can be prevented by the use of this coating. F. Fenton Gilbert, president of the company, was present at the show.

Engineers to Exercise Their Brains

MEMBERS of the N. A. S. E. are taking a live interest in an Engineering Problems Contest announced by the National Educational Committee. Beginning November, 1923, and each month to July, 1924, there will appear a list of 30 questions covering arithmetic, mensuration, heat, pneumatics, hydromechanics, applied mechanics, pumps and condensers, steam boilers and steam engines, one subject each month.

Active members in good standing are eligible, except graduates of colleges and technical schools. Questions will be classified into three grades, elementary, intermediate and advanced, and a man starting in one grade must continue in that grade to the end of the contest.

Answers will be judged and the prizes awarded by the Committee. Five prizes are offered—$400, $250, $125, $75 and $50—the best percentage for the term of the contest to take first prize, regardless of the grade in which the contestant is working, and so on for the other prizes. The only condition is that an average percentage of 70 or over must be maintained up to May, 1924, in order to receive a prize. One month from time of publication is allowed for sending in answers to any set of questions, the contest closing Aug. 1, 1924. Any eligible contestant may enter, however, up to midnight of May 1, 1924, by solving and sending in answers to all problems published up to that time in any one grade.

Details in regard to the form in which answers are to be submitted and further information can be had from Frederick L. Ray, 1124 Victory Ct., Anderson, Ind., to whom all answers are to be sent.

Associations of the N. A. S. E. may enter the contest as well as individual members.

Industries of New England Study Power Situation

AT A CONFERENCE of delegates to the Associated Industries of Massachusetts at Boston recently, it was voted to appoint a committee of 30 engineers, manufacturers and public service men to make a comprehensive investigation of the power possibilities of New England. This work will be done in conjunction with a small committee which was appointed some time ago for a survey of the power resources. The new committee will work more along the lines of methods of financing and to secure an outlet for power, mostly hydroelectric current, while the former committee worked along the lines of laying out a source from which such power would be secured and the possible linking up of existing lines, extensions for linking up these lines and the general topography of the whole of New England.

It is expected that the former committee, composed of engineers and manufacturers, will submit its report within a few weeks, most of the surveying having been completed. The Associated Industries had been interested in considering purchase of power from Canada, but unfavorable comment from Canadian sources has resulted in turning attention wholly to New England resources.

Chicago A. S. M. E. Will Give Day to Power Meeting

JANUARY 15, the Chicago Section of the American Society of Mechanical Engineers is planning to devote day and evening to a symposium on power subjects. This will be the first visit to the section of the newly elected president of the society, Fred R. Low. The tentative program calls for a morning session with two papers, one dealing with the central station power plant and the other with the industrial power plant. Stokers, of underfeed, forced-draft and chain-grate types, pulverized coal and boiler-room auxiliaries, are the subjects to be discussed during the afternoon. In the evening there will be a dinner meeting at which President Low and C. F. Kettering, president of the General Motors

Research Laboratory, Dayton, Ohio, will be the principal speakers. It is planned to send invitations to the various sections within visiting radius from Chicago thus making the meeting regional in character.

Edison Medal Awarded to John Lieb

FOR THE YEAR 1923 the Edison Medal has been awarded by the Edison Medal Committee of the American Institute of Electrical Engineers to John William Lieb, of New York, N. Y., "for the development and operation of electric central stations for illumination and power."

Mr. Lieb was born in Newark, N. J., in 1860. He was granted an M. E. Degree by Stevens Institute of Technology, Class of 1880, and the honorary degree of Doctor of Engineering in 1921. In 1880 he entered the employ of the Brush Electric Co., of Cleveland, as a draftsman and in 1881 became assistant in the engineering department of the Edison Electric Light Co. In 1882 Mr. Lieb became assistant to Mr. Edison and was engaged in experimental research. He then became electrician of the Edison Electric Illuminating Co., of New York, in charge of the installation and operation of the pioneer station at Pearl Street. In November, 1882, Mr. Lieb went to Milan, Italy, to represent Mr. Edison in connection with the design, installation and operation of the Milan central station. He eventually became technical director of the Societa Generale Italiana di Elettricita Sistema Edison, and from 1883 to 1894 was engaged with the Italian company in power station work and in the manufacture of lamps, dynamos, motors and other apparatus. It was under his direction at Milan that some of the earliest experiments were made in parallel operation of direct driven alternators, the operation of large synchronous motors, and long distance transmission of high-tension alternating current by underground cables. In 1894 Mr. Lieb returned to New York as assistant to the vice-president of the Edison Electric Illuminating Co., becoming vice-president and general manager. On the organization of the New York Edison Co. he was made associate general manager and then appointed to his present position of vice-president, in general charge of operating, also for the affiliated electric companies in the metropolitan district. Since 1900 Mr. Lieb has also been president of the Electrical Testing Laboratories. Mr. Lieb has taken a prominent part in the work of many of the organizations in the electrical and allied fields.

Congressional Action for Coal Control Proposed

REPRESENTATIVE Allen Treadway, of Massachusetts, proposes in a bill, introduced in this sessions of Congress, the establishment in the Interstate Commerce Commission of an anthracite coal bureau. This bureau would require the registration of all persons engaged in the coal business and would control the shipments by car and the quantities in the shipments.

Representative Treadway states in general that the basis of the bill is in the declaration of public interest being paramount to private monopoly, founded on the report of the United States Coal Commission. The grain futures act, which has been upheld by the United States Supreme Court, bears a similar declaration. The bill would enact into federal law, the principle that anthracite coal is a factor in public welfare and cannot be diverted to private monopolistic benefit.

The bill provides for a director of the proposed bureau, with authority over shipments of coal and distribution, along with supervision regarding quality. This bureau would have the expert assistance and advice of the Bureau of Mines.

Oil Circuit Breaker Is Four Stories High

A SWITCH built on the plan of a skyscraper in order to conserve ground area is one of the recent developments of the General Electric Co. An equipment of 28,000-v., triple-pole oil circuit breakers which, including control and operating mechanism, occupy a space just 5 ft. square and rise 58 ft. into the air, is now being built for the Hudson Avenue generating station of the Brooklyn Edison Co.

Departure from the regular order of design lies in the arrangement and control, rather than in the breaker units, which are of the standard FK-130 type. The units are placed one above another, one phase to a floor, with the operating mechanism on the uppermost floor, giving rise to the designation of "four-story" oil circuit breaker.

60,000-Kw. Extension for Long Beach Plant

SOUTHERN California Edison Co. is planning to build a 60,000-kw. extension to the Long Beach steam power station, near Los Angeles, and has awarded the contract to Stone & Webster, Inc., of Boston, Mass., for the design and construction. The Long Beach station is part of the Southern California Co.'s system which supplies electric light and power to a large territory in southern California including the San Joaquin Valley. The present system includes two hydroelectric power plants built by Stone & Webster on Big Creek, one of which operates under a head of 2150 ft. and is the highest head plant in the United States.

News Notes

H. S. STOCKDALE has been appointed district sales manager of the Pittsburgh territory with offices in the Oliver Bldg., by the United Machine & Manufacturing Co., of Canton, Ohio.

COL. THEODORE A. LEISEN, recently consulting engineer to the Board of Water Commissioners of the City of Detroit, has left for Omaha, Neb., where he has accepted the position of general manager of the Metropolitan Utilities District of Nebraska.

BROOKLYN EDISON Co. has recently contracted with the Westinghouse Electric & Manufacturing Co. for a large order of switchboard equipment. The order, amounting to approximately $600,000, includes 97 truck type switchboard units, 149 induction feeder regulators, one 1300-kw., 4-unit, motor generator set, and eleven 5-kw. battery charging motor generator sets. This apparatus will be installed by the Brooklyn Edison Co. in the new Hudson Ave. station, the Charles Place, Fifth Ave., West Twelfth St., Ainslie, and Kings Highway substations.